IRRIGATION AND WATER-SUPPLY

The present Volume forms the Second of a Series of

FARM ENGINEERING TEXT-BOOKS

By PROFESSOR JOHN SCOTT.

The following are now ready:—

Draining and Embanking. With 68 Illustrations. Price 1s. 6d.

Irrigation and Water-Supply. With 34 Illustrations. Price 1s. 6d.

To be followed by the undermentioned, which are in active preparation:—

Farm Roads, Fences, and Gates.

Farm Buildings.

Field Implements and Machines.

Barn Implements and Machines.

Agricultural Surveying, Levelling, etc.

SCOTT'S FARM ENGINEERING TEXT-BOOKS.

IRRIGATION AND WATER-SUPPLY

A

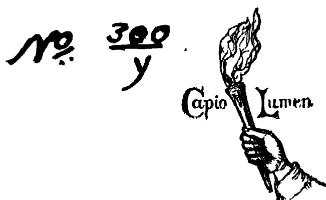
PRACTICAL TREATISE

ON

WATER-MEADOWS, SEWAGE IRRIGATION AND WARPING; THE CONSTRUCTION OF WELLS, PONDS, AND RESERVOIRS; AND RAISING WATER BY MACHINERY FOR AGRICULTURAL AND DOMESTIC PURPOSES.

By JOHN SCOTT

LATE PROFESSOR OF AGRICULTURE AND RURAL ECONOMY AT THE ROYAL AGRICULTURAL COLLEGE, CIRENCESTER; AUTHOR OF "THE FARM VALUER," "RENTS AND PURCHASES," ETC.; AND ONE OF THE AUTHORS OF MORTON'S "HAND-BOOK OF THE FARM" SERIES.



LONDON

CROSBY LOCKWOOD AND CO.

7, STATIONERS' HALL COURT, LUDGATE HILL

1883

LONDON:
PRINTED BY J. S. VIRTUE AND CO., LIMITED,
CITY ROAD.

PREFACE.

THE full advantages of irrigation are best realised in dry tropical or semi-tropical countries, where rain falls only at long intervals. There, many a large tract of land, that is naturally barren and worthless, is, with this provision, seen to yield rich and abundant crops. In these countries irrigation is a commercial necessity, and large sums of money are profitably expended on it.

In countries of Northern Europe, where the climate is humid and temperate, by far the largest outlay is incurred, not in irrigation works, but in draining lands which suffer from an excess of moisture. It can rarely be necessary, on such soils, except in periods of exceptional drought, to have recourse to the double and expensive process of subsoil draining followed by irrigation. Subsoil draining is in itself a protection against drought; and deep tillage and frequent hoeing and stirring of the surface soil are to some extent substitutes for rain, in the cultivation of plants. Still, in a climate like that of Britain, where the rainfall varies from 15 inches or less annually in dry districts in dry years, to 150 inches or more in wet districts in wet years, it would be strange if the extremes of drought and flood did not occasion, at different times and in different places, the need of irrigation as well as of drainage.

There are, indeed, few English farms that could not, in average years, with a good command of water for irrigating crops, be made to produce far more largely than they do, and that without incurring outlay upon costly engineering works. It is not very wide of the mark, perhaps, to affirm that English water-meadows are doubled in value by irrigation; and a good supply of water has been known to increase the value of arable land from four to ten fold.

But because the need of irrigation is not incessant, and because abundance of water is within reach of every farmer in this country, and can generally be drawn upon freely and without cost, the watering of crops in dry weather suffers unaccountable neglect amongst us. We have seen crops allowed to fail from drought, in situations where two or three furrows marked out by a plough, and connected with some neighbouring watercourse, could have been made the means of watering many acres of land.

In countries where irrigation is not such a casual necessity as it is in our own, the agriculturists are more careful to adapt their lands for it, though in most cases they have to pay dear for the water they use, and often also have to raise it, at great additional expense, to the elevation of the lands to be watered.

On small holdings, and especially in garden culture and upon market-garden farms, where the value of the produce is greater than in ordinary farming, the possibilities of irrigation, and the benefits of its practice, can scarcely be exaggerated, even in situations where considerable expense may be involved in obtaining and applying the necessary quantities of water.

Agricultural water-supply, however, involves much besides the watering of crops. With the live stock of

the farm, the need of water is more urgent than for irrigation, and the dependence of live stock on artificial supplies is more incessant. Only those who have had experience in stock-keeping on a large scale, in regions where there is little or no rainfall during many months of the year, can realise the full importance of this part of our subject. Horses and cattle require on the average about five gallons each, and a sheep about half a gallon, per day, in dry weather. On waterless formations, therefore, any means of rendering water easily come at does much to enhance the value of the land for grazing purposes.

In the stock-yards, as in the pastures, a plentiful supply of wholesome water is a first necessity; yet what is the real state of matters in this respect, on many farms? A month's dry weather sees the water-supply exhausted; or cattle are compelled to drink from a dirty duck pond, or from some stagnant hole which is too often the main receptacle for sewage and liquid manure. Is it wonderful that animals compelled to drink such water are injured in health? that epidemics break out amongst them? or that milk from cows so treated is a source of danger and disease to the consumers of it?

The supply of water for agricultural engines is now only of secondary importance to the requirements of live stock; and water-power, for driving threshing and other machines, if not an absolute necessity, is certainly a great advantage in most situations. Every acre of land cultivated by steam requires about 100 gallons of water for engine use, and it is of much consequence that this supply should be accessible at every site likely to be occupied by the engines in cultivating an entire farm.

Most important of all, however, is the question of supplying the farmhouse and the cottages of the farm with abundance of pure water. Every adult consumes daily about half a gallon of water, and of course large quantities are required for domestic purposes beyond what is actually consumed in food and drink. The total daily requirements vary from about three gallons in cottages, to ten or fifteen gallons in large houses, for each person. Unless, at the same time, the water is good, a perfectly healthy condition of the body cannot be maintained. Many of the most dangerous forms of disease are known to be introduced into the system mainly through the agency of bad water. It is imperative, therefore, in the interests of health, that all "doubtful" waters should undergo a complete filtering process, which will not merely remove the grosser impurities but change chemically those in solution, before they are considered fit for drinking.

The various methods of irrigating land; of obtaining water by artificial means, and of storing and purifying it for use; of constructing wells, ponds, and reservoirs; and of raising water by machinery, are the subjects discussed at length in the following pages.

CONTENTS.

LIST OF ILLUSTRATIONS.

IRRIGATION AND WATER-SUPPLY.

CHAPTER I.

IRRIGATION.—THEORY AND EFFECTS.

IRRIGATION is the watering of land at will. And artificial watering is all the more effectual, as well as all the more easy of accomplishment, from the fact that the need of it is not incessant, but may generally be confined to a few months of the year.

There are few farms, perhaps, that it would be advisable, even were it possible, to lay wholly under irrigation: at the same time, there are few farms that, in average years, could not have been made to largely increase their crops had they had full control of the necessary supply of water.

On many farms which periodically suffer from drought, it is quite possible to control the water supply to a much greater extent than is done at present, and with the best results. Costly engineering works, by which water is conducted long distances for purposes of irrigation, are not practicable in general agriculture; yet many streams which now run by unutilized might be turned to account, and channels which now permit the escape of winter rains might, in

many cases, be dammed with little expense, and the rainfall saved for irrigating the summer crops.

On the prairies the plans would sometimes have to be different, and the expense would probably be greater; but the results obtained would well reward the outlay. Where running streams and storage water were not available, tube-wells might be sunk at points where the water could be led across a vast plain, or down a valley, in irrigating streams and ditches, until it has been wholly absorbed by the soil. In California single wells are often made to irrigate sufficiently hundreds of acres, by the aid of a reservoir into which their waters are discharged when the soil does not require them, and there retained until the thirsty soil calls for irrigation.

Reasons for Irrigation.—Soils which do not contain more than 5 to 9 per cent. of moisture, Professor Church tells us, will yield none of it to the plant. Seeds, however, must absorb a very large quantity of water to induce germination. Young growing plants, also, require large supplies of water, and, indeed, all vegetable produce when in a growing state. The actual proportion is often 70 to 80 per cent., and sometimes as much as 90 to 96 per cent. The whole of this water is absorbed by the plant through the soil, and none of it directly from the atmosphere. When the daily evaporation from the leaves exceeds the amount of moisture the plant can take up by its roots, the plant must wither and die: in other words, it succumbs to drought.

Professor Johnson says: "The great deserts of the world are not sterile because they cannot yield the soil-food required by vegetation, but because they are destitute of water . . . . Poor soils give good crops

in seasons of plentiful and well-distributed rain, or when skilfully irrigated; but insufficient moisture in the soil is an evil that no supplies of plant-food can neutralize."

The reason of this is obvious; for, in addition to the water which enters into vegetable composition, plants can only take up their food in a fluid condition. Lawes and Gilbert, at Rothamsted, proved that an acre of wheat in five months and eighteen days evaporated through its leaves 335¼ tons of water. Every drop of this water was more or less instrumental in transporting an atom of food from the soil to some part of the plant, and when the deposit was made, the water which was no longer needed passed off through the leaves.

The reasons for irrigation are summed up by Professor Church* as follows:—

"1. To make up for the absence of irregular seasonal distribution of rain, or for a local deficiency of rainfall.

"2. Sometimes a particular crop is irrigated because the plant is of an aquatic or semi-aquatic nature.

"3. To encourage early and rapid growth, by warmth of the water, or by the dissolved plant-food which it contains.

"4. That the land may be enriched and its level raised by means of the deposit from the water."

The third of these reasons, he points out, "is the determining cause of nearly all the artificial watering of land in temperate climates. It is not performed because the soil is dry and hot, for it is carried out mainly in the wettest and coldest months of the year. It is not performed because the crop to be raised is of

* "Encl. Brit.," 9th ed., art. Irrigation.

an essentially aquatic nature, for ordinary grasses and meadow herbage are principally watered. But it is performed that growth may be stimulated and fed through certain agencies which the water brings to bear upon the vegetation in question."

Effects on Soil.—"The immediate effect of irrigation upon the *consistence* of the soil is to soften it and render it more easily penetrable by the plough and by the roots of the plants. Hence, in dry climates, water is frequently applied before ploughing, at the rate of about 400 to 500 cubic yards per acre, or barely enough to loosen the earth to the depth of a foot without drenching it. But it is most important to observe that the ultimate effect of long-continued irrigation is to condense and harden the surface to a very inconvenient degree.

"Irrigation affects the *quality* of the soil by introducing into it common air and other gases, and vegetable and mineral matter held in suspension or solution by the water. In most cases the substances so introduced are beneficial to vegetation; but in some they are highly noxious. Even the water of large rivers sometimes, as has been observed in India, deposits on the surface, or introduces into the texture of the soil, salts, which in the course of time render it wholly sterile."

It likewise acts upon arable soil by facilitating the decomposition of soluble organic and inorganic matter contained in it, and carrying off such matter from it. The extent of this latter action is disputed; but it must be considerable, for constituents of vegetable growth have been found in under-drain water from cultivated fields; and large tracts of ground, impregnated with salts to such a degree as to make them

incapable of cultivation, have been rendered fertile by washing with fresh water.

On undrained land, irrigation often injuriously affects the subsoil by charging it with water which stagnates in it, and renders it cold and sour to the roots of plants which descend into it.

It also exercises an important influence on the water-supply of lands lying at a lower level, by diverting from their natural channels streams which originally flowed through such lands; and on the other hand, by discharging upon their surface surplus waters from irrigated fields, or by saturating them with water, conveyed to them from such fields by subterranean infiltration. These effects are seen, not only in the soil itself, but in the diminished or augmented volume of spring and well water.

Finally, irrigation modifies the temperature of the soil beneficially or injuriously by communicating or abstracting heat, and by promoting evaporation from the surface, which is necessarily attended with some cooling of the ground.*

Effects on Vegetation.—Watering the soil promotes the germination of the seeds of cultivated plants, and, unfortunately, of weeds; and water is in, and of itself a necessary element of vegetable growth. Besides this, it is never quite free from extraneous matter, and it always contains, in solution or in suspension, foreign substances useful or injurious to vegetation. Hence, in climates and on soils where the natural supply of water is insufficient for the normal growth of plants, remunerative agriculture is impossible without artificial arrangements for procuring and administering it.

In many cases, however, although the quantity of

* Professor Johnson.

the product is increased, there is a deterioration in the quality of it. There is no doubt that all crops which can be raised without watering are superior in flavour and in nutritive power to those grown by the aid of irrigation. Garden vegetables, in particular, when profusely watered, are so insipid as to be hardly eatable. Comparative weight is, therefore, not always a true test: the heaviest potatoes, for example, are not the best.

"Moderate irrigation of herbaceous plants," says an Italian writer, "accelerates their germination and growth, but it checks the ripening of their seeds; and if water is applied in excess, it renders their texture less firm and substantial, and at the same time more subject to decomposition and waste."

Theory of Irrigation.—"Although," remarks Professor Church, "in many cases it is easy to explain the reason why water, artificially applied to land, brings crops or increases the yield, the theory of our ordinary water-meadow irrigation is rather obscure. For we are not dealing in these grass lands with a semi-aquatic plant like rice, nor are we supplying any lack of water in the soil, nor restoring the moisture which a plant cannot retain under a burning sun.

"We irrigate chiefly in the colder and wetter half of the year, and we 'saturate' with water the soil in which are growing such plants as are perfectly content with earth not containing more than one-fifth of its weight of moisture.

"We must look, in fact, to a number of small advantages, and not to any one striking beneficial process, in explaining the aggregate utility of water-meadow irrigation.

"We attribute the usefulness of water-meadow irrigation then to the following causes:—

"1. The temperature of the water being rarely less than 10° Fahr. above freezing, the severity of frost in winter is thus obviated, and the growth, especially of the roots of grasses, is encouraged.

"2. Nourishment or plant food is actually brought on to the soil, by which it is absorbed and retained, both for the immediate and future use of the vegetation.

"3. Solution and redistribution of the plant food, already present in the soil, occurs mainly through the solvent action of the carbonic acid gas present in a dissolved state in the irrigation water.

"4. Oxidation of any excess of organic matter in the soil, with consequent production of useful carbonic acid and nitrogen compounds, takes place through the dissolved oxygen in the water, sent on through the soil, where the drainage is good; and

"5. Improvement of the grasses, and especially of the miscellaneous herbage, of the meadows is promoted through the encouragement of some, at least, of the better species, and the extinction or reduction of mosses and of unnutritious weeds."

Drainage in connection with Irrigation.—Irrigation is only useful when the water is entirely at command, both to lay on and to take off at pleasure. Drainage is, therefore, a necessary preparation for irrigation.

Any want of good management on this point will entail loss and disappointment. This applies, not merely to the period of intermission which may be advisable between the waterings, but also, on stiff soils particularly, to the thorough under-drainage of the land.

It need not be feared that the thorough drainage of

irrigated lands will do more harm than good by washing the most valuable constituents of plant food out of the soil. Phosphoric acid and potash, which are the most valuable components of soils and manures, Dr. Voelcker tells us, are retained in the land almost entirely; while lime, magnesia, sulphuric acid, chlorine, and soluble silica, the less important because more abundant and widely distributed mineral matters, pass into the water of land-drainage in considerable proportions. There may be a loss of nitrogen, however, if the land has been manured with a nitrate, and its application is immediately followed by irrigation. Still the good effects of drainage will always far more than compensate for any losses which may occur in this way.

Impoverishing Effects of Irrigation.—Water, as has been pointed out, stimulates production by its solvent action on the constituents of the soil and of manures. But for this very reason, prolonged irrigation is apt to become injurious, unless the water is rich, or unless adequate manuring, cultivation, and drainage attend its practice. In well irrigation especially, and also in canal irrigation, the water used is often of little fertilizing value, and unless it is rationally used, the results must be disappointing. For the first year or two after it is brought into play it will probably increase the crops; but without the concurrent application of the agencies already mentioned for maintaining fertility, it must eventually reduce the productive power of the soil.

This is exactly what has happened in certain districts of Upper India, where well and canal irrigation has been persisted in for years and generations even, without any attempt at sustaining fertility by the application of manures, or to lessen the impoverishing effect of the water by good drainage and cultivation.

"The real reason," says Colonel Corbett,* "of the falling off in the produce of canal-irrigated lands appears to be the consolidation of the pan by the treading of the cattle in ploughing, and the hardening of the upper soil in irrigation. This causes shallower ploughing, the roots of plants have less depth of soil in which to search for food, and cannot force their way into the hardened pan; and there is the alternate soaking and drying of the land, during which the natural salts of the earth are gradually brought nearer the surface by capillary attraction.

"This process may go on for some years before the lands show any excessive amount of *reh* on the surface; but the soil is steadily being poisoned by its accumulation near the surface, which accounts, together with the increased hardness of the soil, for the diminished fertility of lands some time under irrigation."

Influence of Tillage in mitigating Drought.—Hoeing and frequent stirring of the soil are good substitutes for rain. Those parts of the garden that are most frequently cultivated show the best results in dry weather. A deep, well-manured soil suffers much less from drought than a shallow soil. Under-draining also is a safeguard against drought. The course of the drains can easily be traced in a dry season by the ranker growth of vegetation above them.

Deep cultivation keeps the soil loose and open, and allows the water to sink into it and escape evaporation. In the case of deep cultivation generally, over a country, more especially a level country, there is a reservoir of water under every field sufficient to supply the wants of vegetation, held there by the soil itself.

A writer in the *American Agriculturist* states that,

* "On the Climate and Resources of Upper India."

since some of the great plains of America have been broken up by the plough, a great amelioration of local climate has taken place. "As soon as the tough sod has been ploughed, and the soil been mellowed and made absorbent, the rain soaks into the ground instead of flowing off, and, percolating through the subsoil, supplies springs, which break out in low spots and furnish water for new rills and brooks. The atmosphere is no longer parched, but becomes moist, and its former extreme variations of temperature do not occur. The climate changes, and the moisture of the air and the consequent rainfalls are increased. A new circulation is established, and the storms and showers are those of a temperate instead of a torrid zone. Facts have shown that these conclusions are correct, and the observations taken in many places near the hundredth meridian, and eastward to the Missouri River, indicate a greatly increased rainfall, the increase amounting, in many cases, to several inches a year. Farmers no longer fear disastrous droughts, and there are few localities where their business is safer."

CHAPTER II.

PRACTICAL ADVANTAGES OF IRRIGATION.

In a climate like that of the British Isles, one can scarcely realise the full advantages which attend irrigation in tropical and semi-tropical countries. In California and Mexico, in Egypt and India, in parts of Southern France, Spain, and Italy, and elsewhere, where rain falls only at lengthened intervals, there are vast tracts of land, now contributing bountifully to the world's commerce and industry, that would be absolutely barren and worthless but for this provision.

In the South-western States of America there are many million acres of the most splendid land now lying idle and waste, unable to find purchasers at even nominal prices, because, without the means of irrigating and watering them, they are practically useless both for cultivation and for stock-raising. Yet the very same lands, which go a-begging at fifty cents an acre, in their natural state, when a supply of water has been brought to them, are eagerly purchased at $5,* $10, and even in some cases at $20, and upwards, per acre.

In Colorado, where land is of little value to the farmer unless water is assured, Mr. Pabor tells us that a quarter-section (160 acres) becomes worth at least

* 1 dollar = 4s. 2d.

$10 per acre when an irrigating canal has been built. Water has a commercial value of $15 per acre, when in the shape of a water-right, which is a perpetual claim upon a canal for a certain amount of water each year. When water is rented by corporations to consumers it has a yearly average value of $2 per inch, running continuously throughout the growing season, which amount is considered sufficient to irrigate one acre of grain land.

In Madras, taking an average of thirteen improvements, irrigation shows a net annual gain in revenue, after deducting all charges, of 134 per cent. per annum on the capital.

In Spain, unwatered land of the first quality sells for £32 per acre; when irrigated, the same lands bring £128 per acre. In the same country, second-class land, selling at £20 per acre, is at once increased in value to £100 per acre; third-class land, worth £12 per acre, is increased to £72; fourth-class land, worth £6 per acre, is increased to £60, when irrigated. A good supply of water thus increases the value of land from four to ten fold.

In Italy, the increase due to irrigation is also very great. Mr. Jackson puts it at 50s. on sandy soil, and at 40s. on clayey soils, per acre, annually; which is obviously an under estimate if these figures are meant to represent the increase of produce due to irrigation, but would probably be near the increased rental value.

In France, where irrigation is not an absolute necessity, as in Spain and Italy, it is generally considered that land is worth 50 per cent. more when it can be irrigated than when it cannot. In Vaucluse, according to Mr. Moncrieff, the rental of good land is about

£3 4s. unirrigated; if irrigated, it rises to about £4 3s. per acre.

In England, where irrigation is chiefly confined to the watering of meadows, the produce of grass is at least doubled by the operation. In favourable situations, and in good seasons, an irrigated meadow affords —(1) Early spring grass to feed stock, in particular ewes and lambs; (2) a good crop of hay; and (3) a good crop of after-math. A dry meadow of the same quality would only afford—(1) an inferior crop of hay; and (2) an inferior after-math.

It is not, perhaps, too much to assume that the meadow will be all the spring crop the better by watering.

To give these advantages a money value, it may be said that, in England, if a dry meadow of good quality is worth £2 per acre to rent, the same land, irrigated, will probably be worth £5 per acre.

Water meadows not only afford grass at an unusual season, and when most wanted, but the hay crop is more certain and larger; and the land requires no manure. These advantages may well be worth an additional £3 per acre on good land; while upon poor land the increase will be proportionately greater.

CHAPTER III.

CIRCUMSTANCES FAVOURING IRRIGATION.

Water Supply.—The first consideration, and one common to all lands, is the question of water-supply, and the possibility of applying that water, or a portion of it, for irrigation purposes.

Where water can only be procured by sinking or boring wells, or by storing rain or flood water in tanks and reservoirs—or where the lands are on a higher level than the source of supply, and the water has, consequently, to be raised by artificial means—the cost in either case may be greater than the profit to be derived; and under such circumstances irrigation will often be deemed impracticable.

Streams, where they exist, furnish the most ample and most economical supply of water. This is particularly the case when the water can be taken directly from the stream, and brought upon the field by a short conductor.

Springs are often advantageously situated for irrigating lower lands by gravitation, and will, as a rule, furnish more water than would be suspected. A continuous flow of 1 cubic foot of water per second, during twenty-four hours, is sufficient to cover four acres of land to a depth of nearly 6 inches. One such spring would, therefore, suffice to irrigate many fields,

watering them alternately. Where several small springs occur near each other, connecting drains can often be put in, and the waters collected and brought into one channel.

Canals which serve for irrigation are frequently only conveyors of water from distant rivers, or from natural lakes. If a canal is formed with the express object of watering a given area of land, the capacity of the canal should be large enough to provide a flow considerably in excess of the actual quantity of water required. Where the water has to be carried a long distance, and the soil is porous, the loss by filtration and evaporation may amount to 25 and even 33 per cent.

Catch-water Tanks and Reservoirs.—In many cases where irrigation is carried on, the supply of water is obtained by impounding the winter rainfall for use during the dry season. The flood-water, in very dry districts even, when stored and made available at the right season, is found amply sufficient for the production of good crops.

Assuming that an inch of water is the least quantity that should be applied at each watering, this, over one acre of surface, is equal to 3,630 cubic feet, or 27,152 gallons. To irrigate 30 acres once, at this rate, would require a tank capacity of 108,900 cubic feet, or a tank exactly ¼ acre in extent and 10 feet deep; and to irrigate 30 acres four times, or 60 acres twice, would require a tank four times as large, or 1 acre in extent and 10 feet deep.

A tank or reservoir can often be formed by merely erecting a dam or embankment to impound the water in a natural basin or ravine. Indeed, it will seldom pay to make a ground-tank where the impounding

basin has to be wholly excavated. A tank 1 acre in extent and 10 feet deep contains 16,133 cubic yards of earth, measured in place; and this cannot, under the most favourable management, be removed for less than 2d. per yard, or £134 8s. 10d., and generally the cost will reach 4d. per cubic yard, or even more. Even at the smaller sum the outlay would be even £4 10s. per acre for 30 acres; and there are few cases, perhaps, where it would pay a tenant farmer to incur that expense, although the improvement would be permanent, and would ultimately, no doubt, repay itself.

Wells.—Where no better method of procuring water can be devised, wells may be resorted to. The great objection to wells, however, is not merely the first cost, but generally the after-expense of raising the water.

Artesian wells are often recommended as a source of water for irrigation; but they cannot always be depended upon for this purpose, as few of them can yield an adequate supply of water. At the best "wells can only be depended upon for such a small supply as would serve to irrigate a garden or small market farm, where the large value of the crops admit of raising water for a lengthened season, and storing it in reservoirs for use in emergencies. The idea that artesian wells may be made a source of supply for completely irrigating large tracts of land, if ever held by over-sanguine persons, must be abandoned. For partial irrigation they may be made available; but the quantity of water needed for the irrigation of a few acres of land only, in localities where there is no summer rainfall, as upon our western plains, is far beyond the capacity of any artesian well to supply, unless it be one of extraordinary volume.

"Not long ago the *Scientific American* editorially

announced that one artesian well would supply a farm of 640 acres upon the plains with water for irrigation, and would also form a nucleus for many large stock farms.

"The late Horace Greeley, who, although an enthusiast upon this subject, was more nearly correct, thought one artesian well would serve to irrigate a quarter-section of land, or 160 acres.

"An artesian well, 6 inches in diameter, would give a stream of 28 square inches, and would deliver 32 quarts per second, if the flow were at the rate of 4 miles an hour.

"Such a well would furnish an inch of water per day for 28 acres, or an inch a week for 196 acres, which would be a very insufficient quantity to irrigate dry open soils in places where the climate is arid.

"The cost of such a well would be at least $5,000 to $10,000, or more than the value of the land when irrigated." *

It will be seen from what follows in another chapter that these estimates of the capacity of artesian wells are far short of the results actually obtained by sinking wells in Australia and elsewhere. Tube-wells, too, can be put down at a comparatively trifling expense, compared with the outlay which has in many cases been incurred in sinking artesian wells.

The multiplication of wells in any district, it need scarcely be remarked, has the effect of lowering the spring level. This creates a necessity for deeper wells, causing the water to be raised from a greater depth, and entailing more expense.

Use of Drainage Water for Irrigation.—It will sometimes happen that drainage water can be utilized for

* Stewart, "Irrigation for the Farm, Garden, and Orchard."

irrigation purposes; but we by no means advocate the theory sometimes advanced that drainage is imperfect unless accompanied by irrigation. We do not admit the general truth of the proposition that on wet soils it is necessary to have recourse to the double and expensive process of deep draining, followed by irrigation. There is, doubtless, a certain medium depth of drain, dependent of course on the nature of the soil and subsoil, which will remove the excess of moisture in wet weather, as from a sponge saturated with water, and yet retain, like a damp sponge, sufficient moisture for the purpose of vegetation in dry weather. This object, as already explained, may be greatly promoted by deep and frequent cultivation. When the drainage water from high lands can be used in irrigating lower lying lands which are naturally in want of moisture, it may be done with advantage.

Situation.—The lands that admit of irrigation with most success are such as lie in low situations on the borders of rivers, or in sloping directions on hill-sides, where a command of water can be obtained from higher ground. The latter may often be irrigated more profitably than the former, for they are usually less productive in their natural state; while they can be watered at less expense for laying out the ground and with a less quantity of water. In tank or well irrigation, or where there is an impounding reservoir, the situation of the lands to be watered is comparatively immaterial, provided the source of supply is at a higher level.

Soil.—The soils best adapted for irrigation are those of a light and porous nature, such as sands and gravels. Clay soils, and also peat soils, are not so often benefited by it, except in dry and tropical climates, where the

nature of the soil is of less importance than the ability to give it an artificial watering in seasons of drought.

These remarks, of course, have reference more particularly to the surface soil. A retentive surface soil prevents percolation, favours evaporation, and cools the land, which are serious disadvantages in irrigation; while a retentive subsoil, underlying a porous surface soil, may be a great advantage in dry climates, as it economises water.

Heavy or clay soils must always be thoroughly under-drained before they can be successfully irrigated. They will also be farmed with most profit when laid down in pasture, for irrigation adds considerably to the labour and difficulty of working them.

The relations of soils to water are extremely various, as will appear from the following table:—

	Percentage of water absorbed.	Percentage of water evaporated.
Loose sand	25	88 4
Ordinary clay soil	40	52·
Loamy soil	51	45·7
Strong clay soil	61	31 6
Garden soil	89	24·3
Peat	181	25·5

M. Debay classifies soils for irrigating purposes under three heads: (1) *Sandy Soils*; (2) *Argillaceous Soils*; (3) *Marshy Soils*. Of these he gives the highest value to sandy soils, the best being a clayey sand, warm, dry, and having some portion of marl in its composition. The finer the grain of the sand, the better adapted is it to irrigating purposes. One feature connected with the irrigation of sandy soils is, the abundance of reeds and rushes which they will produce

when first placed into water; but these will gradually disappear as the plants of a higher class of vegetation increase. Of the argillaceous soils it may be said that the more tenacious and impermeable they are, the worse adapted are they for irrigation; and in such cases, where irrigation is adopted, deep drainage and deep cultivation are most essential. Marshy soils are the least valuable of all for irrigating purposes; but when well drained and managed they are capable of large yields.

Climate.—The success of irrigation depends in a great measure on the climate. It answers better in a dry climate than in a moist one, and where heavy wet seasons alternate with severe droughts, it will only be beneficial in the dry seasons. It will also be more profitable in a mild and genial climate than in one less propitious; as under the former circumstances it will not only afford more ample crops, but also a greater number of them, and more certainty of turning them to good account.

Where the climate is fine, irrigated meadows, for example, will yield three crops; first an early and valuable pasture for ewes and lambs; next a crop of hay; and, latterly, an after-math or good pasture.

In less favourable situations, only two crops can be obtained—one of hay and one of pasture; and neither of them so rich, nor so capable of being turned to great profit.

The question of rainfall is here, of course, all important; and not merely the amount of annual rainfall, but its distribution over days and weeks at various periods of the year.

Crops adapted for Irrigation.—Almost any crop may

be raised by irrigation, but some plants flourish better under it than others, as the object and purpose of irrigation is merely to supply the natural wants of the plants, and not to stimulate them to an undue or excessive growth. The careful irrigator will study the wants of the plants he grows, and also the character of the soil he cultivates.

In our own temperate and humid climate, and in various other countries of Northern Europe, grass meadows seem to be most benefited by irrigation; but in warm Southern Europe, Egypt, India, and other parts, irrigation is chiefly applied to arable lands and crops. It is worth noticing, perhaps, that while in the latter countries irrigation is a commercial necessity, and large sums of money are profitably expended on it, in the former countries, where the climate is humid or temperate, by far the largest outlay is incurred, not in irrigation works, but in artificially draining lands which suffer from a superabundance of moisture.

Of all the cultivated grasses and leguminous plants, rye-grass and lucerne are the two which yield the best results under irrigation. The different species of cabbage, beet, and turnip thrive well with occasional waterings; as do also grain crops, up to the period of inflorescence, after which watering becomes injurious to them, except for a very short interval when the grain is filling.

Many of the plants cultivated for industrial purposes cannot well be grown without artificial supplies of water at certain times. Too much water injures them; yet much of their success depends on their receiving a regulated abundance of moisture. Madder (*Rubia tinctorum*), the sugar-cane (*Saccharum officinarum*), and

many other important plants of commerce are of this character.

The rice plant, and a few others of aquatic or semi-aquatic habits, are extensively grown under swamp irrigation. Watercress is also raised on a large scale, in the neighbourhood of most large cities, under very similar conditions.

CHAPTER IV.

WATER FOR IRRIGATION—QUALITY AND QUANTITY.

Quality of Water.—Although it must often happen that no choice is possible, yet all waters are not alike suitable for irrigating land. The best water for the purpose is no doubt that which brings with it those fertilizing matters which will supply the deficiencies of the soil and the wants of the crop irrigated.

In examining a water, however, as to quality, its dissolved and suspended matters must both be taken into account. Water having no more than a few grains of dissolved matter per gallon answers the purpose in view satisfactorily.

"Should it be thought," says Professor Church, "that the traces of the more valuable sorts of plant food, such as compounds of nitrogen, phosphates, and potash salts, existing in ordinary brook or river water, can never bring an appreciable amount of manurial matter to the soil, or exert an appreciable effect upon the vegetation, yet the quantity of water used during the season must be taken into account. If but 3,000 gallons hourly trickle over and through an acre, and if we assume each gallon to contain no more than one-tenth of a grain of plant food of the three sorts just named taken together, still the total, during a season including 90 days of actual irrigation, will not be less than 9 lbs. per acre."

Clear water, especially if it proceeds from a spring in the same field, produces early and plentiful grass, but not of a good quality; and the land remains unimproved after many years' watering. We have seen the same unsatisfactory result where meadow irrigation was commenced by drawing water from a stream which has its source in the overflow of a lake. The stream is too pure for this purpose, leaving the richer particles in the lake whence it flows. The water, when first applied to the meadows, had the effect of eradicating moss, and helped to decompose waste vegetable matter; and it, therefore, for a time acted as a stimulus with seeming advantage. But when the meadows were annually mown, without an occasional top-dressing, the system in the end produced comparative exhaustion. It must be the same in many other places, where there is no extraneous matter in the irrigating stream, and where irrigation is begun without attending to local circumstances.

Thick and muddy waters, which convey along with them a rich and nutritive top-dressing and deposit it on the land, are productive not only of temporary but of permanent improvement, enriching the soil itself as well as the immediately following crop. In Southern France, Mr. Moncrieff* tells us, the difference between the meadows irrigated with the silt-bearing waters of the Duranee canals, and those of the clear cold Lorgues, is so marked that cultivators prefer to pay for the former ten or twelve times the price demanded for the latter.

Artificial richness is sometimes given to waters used for irrigation, as when the water is taken from the very bottom of a stream in order to carry as much

* "Irrigation in Southern Europe."

sediment as possible along with it on to the land, or where the drainage of sewers is conducted into the irrigating channel. Sewage irrigation, liquid manuring, and the use of light manures dissolved in water, offer the same advantages in a fuller degree, and will be dealt with in more detail farther on in this work.

River waters,—especially such as carry much suspended matter, and such as have received town sewage, or the drainage of highly manured land,—are more suitable for irrigation than water from tanks, wells, or springs. Streams in which fish abound are always considered good for irrigating with. "Hard" waters are also considered better than "soft" waters; this hardness being due to the presence of sulphate and carbonate of lime and magnesia, ingredients which are highly favourable to fertility. It is for this reason that water coming from the chalk formation is so good for irrigation purposes. So again with the water that comes from a granite formation, for it is rich in potash.

Water from forests, moors, and peat bogs, or from gravel or ferruginous sandstone is, as a rule, of small utility so far as plant food is concerned. Water containing much hydrous oxide of iron is generally considered very bad for irrigation; yet Sir John Sinclair tells us that the famous Presley bog in Bedfordshire is strongly impregnated with iron, and that even the water used to irrigate it is partially affected by it. Running water from mines is highly inimical to vegetation; and amongst other injurious sorts of refuse which can find their way into irrigating streams, are the chemical wastes from mills and factories in which the processes of dyeing, paper-making, metal-working, &c., are carried on.

Chemical analysis is the most satisfactory test of the

quality of a water before it is used in irrigation; but some estimate of its probable effects may be formed by observing the natural products, the grasses and other plants, that grow on the banks and borders of the irrigating stream. We do not pretend to give a list of the particular plants which will afford this criteria of excellence in every place, for they will be found to vary with the soil and climate; but every farmer knows the plants which in his district will afford this indication of quality in the water used to irrigate with. "As a rule," says Mr. R. Scott Burn, "the water is of excellent quality if water-cresses (*Nasturtium officinale*), the aquatic ranunculus (*Ranunculus aquatilis*), grow near it; or other plants, such as the pond weeds (*Potamogeton perfoliatus*, or *P. fluitans*), and the speedwells (*Veronica anagallis*, or *V. Beccabunga*). The following plants grow in the neighbourhood of water of middling quality: *Sium cutifolium*, *S. angustifolium*, the mints (*menthæ*). If no plants are observable save the mosses and the sedges (*Carex acuta* and *C. stricta*), the quality of the water may be considered as bad."

Quantity of Water required.—On this point it is impossible to lay down any rule, as the quantity of water required for irrigating land so much depends on the climate, the nature of the soil, the object of watering, and the crop grown.

The more arid the climate, the greater of course the demand for water.

The composition and texture of both the super and subsoil greatly influence the amount of water required. M. Gasparin states that a soil containing 20 per cent. of sand needs irrigation once in fifteen days, while with 80 per cent. of sand it requires irrigation once in five days. A gravelly or sandy subsoil will allow of almost

unlimited percolation; whilst, if it be clayey and retentive, percolation is reduced to a minimum.

The object of irrigating may be merely to make up deficiencies of rainfall and provide sufficient moisture in the soil for the support of a crop; or it may be for the sake of depositing on the land the fertilizing matters which are conveyed by the water. If the latter is the object in view, very large quantities of water may have to be used to produce the required effect.

In Northern Europe, for example, where irrigated meadows are common, large quantities of water are allowed to flow over the fields, the principal object being to manure the land by the sediment thus deposited. In the warmer climates of Southern Europe, India, &c., on the other hand, irrigation is only used to moisten the ground, and to supply by artificial means the want of rain, which is so much felt at times in those countries; and thus it is that the watering which would be effectual in the latter case would be deemed altogether insufficient for the water-meadows of Northern Europe.

Peculiarities of climate and soil, together with the object of watering, will generally have more influence on the amount of water required for irrigation than the kind of crop grown. Nevertheless some crops call for very much larger supplies than others.

The crops watered are usually classed in the following order, with regard to their special treatment and the amount of water they require:—

1. Grass meadows.
2. Lucerne, rye-grass, and other cultivated forage crops.
3. Cabbage, turnips, &c.
4. Beans and peas.
5. Wheat, oats, barley.
6. Sugar-cane, tobacco, indigo, madder.
7. Rice.
8. Gardens and fruit-grounds.

The quantity of water supplied during the season—which in Europe is only about six months in the year, say from April to October—to ordinary ploughed or hoed field crops varies from 20 to 40 inches. In the rice fields, of course, this amount is vastly exceeded; as it is also in the water meadows and many other grass grounds. The proper quantity, as well as the season for applying it, must necessarily vary under any particular soil and climate.

A flow of water, equal to 1 cubic foot per second, will cover 4 acres to a depth of nearly six inches in twenty-four hours; and, continued one hundred days, it will cover 400 acres to the same depth, or 200 acres with 12 inches of water. A cubic foot of water per second throughout the season has been found sufficient to irrigate from 30 to 90 acres of rice, according to the rainfall of the district.

Moncrieff gives the following table, by M. Conte, showing the acreage of each crop watered on the St. Julien Canal, and the amount of water required for each, as a fair specimen of the irrigation of Southern France:—

	1. Surface watered.	2. Percentage borne by each to the whole.	3. Number of acres of each, irrigable per cubic ft. per second.	4. Quotient of column 1 by column 3.
	Acres.			Discharge in cubic ft. per second.
Gardens	1183·9	16·	28	42·6
Meadows . . .	789·3	10·8	70	11·3
Lucerne grass . .	592·	8·	70	8·4
Beans	690·6	10·2	50	13·8
Madder	394·6	5·3	168	2·3
Chardon	296·	4·	184	1·6
Sundry other crops	3340·1	45·7	454	7·3
Total . .	7286·5	100·	—	87·3

The table gives a mean duty of 83·4 acres watered during the six months of irrigation, per cubic foot per second. But, as Mr. Moncrieff points out, the large area classified as sundries makes this result of little value, many of the crops included in this area being only watered in an emergency, and not regularly, like some of the other crops. If, for example, a vineyard is looking drooping, or a field of wheat turning prematurely yellow, it gets a watering. In cases of great droughts, wheat is occasionally watered as many as three times.

The meadows are watered from about every seven to about every fifteen days, and yield three crops in the season. Lucerne grass is irrigated about as often as the ordinary meadows, is cut every month, and yields five or six crops during the season. Beans are irrigated every five days. Madder is not often irrigated more than three or four times after being planted out, the last time being immediately before it is dug up.*

In Piedmont and Lombardy, Mr. Jackson tells us,† one cubic foot per second waters 50 to 100 acres of grass land, or only 40 acres of rice. In the Madras Presidency, and in the North-west provinces of India, one cubic foot per second waters, in ordinary seasons, 100 acres of rice, or other very wet cultivation; in very dry seasons 50 acres. The highest duty actually performed in Central India is about 270 acres per cubic foot per second.

The following tables, by Mr. Jackson, furnish some useful details in regard to Italian irrigation:—

* Moncrieff, "Irrigation in Southern Europe."
† "Hydraulic Manual." (Crosby Lockwood & Co.)

I.

—	Absorbed.		Utilised.		Expended.	
	Meadow.	Arable.	Meadow.	Arable.	Meadow.	Arable.
Volume of water in cubic ft. necessary per acre at each watering	5885	8476	9160	9697	15045	18173

II.

—	Meadow land.		Arable land.	
	Watering once in 7 days	Watering once in 10 days.	Watering once in 14 days.	Watering once in 20 days.
Quantity of continuous water in cubic feet per second per acre necessary for irrigation	·02486	·01740	·01501	·01005

III.

—	Meadow land.		Arable land.	
	Watering once in 7 days.	Watering once in 10 days.	Watering once in 14 days.	Watering once in 20 days.
Area in acres that can be irrigated by one cubic ft. per second	40·23	57·47	66 66	99·16

IV.

—	Area in acres.	Sandy soil.	Clay soil.
Supply necessary for each acre of the irrigable area . . .	1·00	·01346	·00924

"Result adopted for calculation of supply to 1 acre: in sandy soil, ·01346 cubic ft.; in clayey soil, ·00924 cubic ft."

"In Table I. the quantity of water sufficient for one irrigation or watering is taken at 15,045 cubic feet for meadow and 18,173 for arable land. It cannot be doubted, by any one conversant with irrigation in India or Spain, that this quantity is excessive.

"The object of ordinary irrigation in hot climates is simply to supply the place of rain and soften the soil, and differs much from the irrigation of lands in colder regions, which, partaking of the nature of sewage irrigation, has for its object the deposition of a fertilizing sediment rather than a supply of moisture.

"This latter description of irrigation being excluded from the project and data under consideration, the former alone has to be dealt with; and for such purposes, in India and in Spain, a watering of 10,000 cubic feet is ample, either for pasture or arable land. One such watering represents a depth of ·23 feet over an acre, and is equivalent to a continuous supply throughout the year of ·000317 cubic feet per second.

"In a hot climate, or with a drier soil, a greater number of waterings might be required, but not a larger supply at each watering."

From the foregoing tables the number of waterings appear to be forty-six and twenty-three in the year for meadow and arable land respectively on sandy soils, and thirty and fifteen on clayey soils. "Leaving out of consideration the fact that these waterings are a half and three-quarters larger than would be requisite in India or Spain, their number seems excessive.

"In India the number of waterings prescribed on the Nageenah Canal, North-west Provinces, is thus:—

For fruit-gardens	8 per annum.
,, hemp	5 per crop.
,, rice, indigo, sugar, tobacco, grass, herbs	4 ,,
,, cotton, wheat, barley, grains, and pulses	3 ,,

I.

—	Absorbed.		Utilised.		Expended.	
	Meadow.	Arable.	Meadow.	Arable	Meadow.	Arable.
Volume of water in cubic ft. necessary per acre at each watering	5885	8476	9160	9697	15045	18173

II.

—	Meadow land.		Arable land.	
	Watering once in 7 days.	Watering once in 10 days.	Watering once in 14 days.	Watering once in 20 days.
Quantity of continuous water in cubic feet per second per acre necessary for irrigation	·02486	·01740	·01501	·01005

III.

—	Meadow land.		Arable land.	
	Watering once in 7 days.	Watering once in 10 days.	Watering once in 14 days.	Watering once in 20 days.
Area in acres that can be irrigated by one cubic ft per second	40·23	57·47	66·66	99·16

IV.

—	Area in acres.	Sandy soil.	Clay soil.
Supply necessary for each acre of the irrigable area . . .	1·00	·01346	·00924

"Result adopted for calculation of supply to 1 acre: in sandy soil, ·01346 cubic ft.; in clayey soil, ·00924 cubic ft."

"In Table I. the quantity of water sufficient for one irrigation or watering is taken at 15,045 cubic feet for meadow and 18,173 for arable land. It cannot be doubted, by any one conversant with irrigation in India or Spain, that this quantity is excessive.

"The object of ordinary irrigation in hot climates is simply to supply the place of rain and soften the soil, and differs much from the irrigation of lands in colder regions, which, partaking of the nature of sewage irrigation, has for its object the deposition of a fertilizing sediment rather than a supply of moisture.

"This latter description of irrigation being excluded from the project and data under consideration, the former alone has to be dealt with; and for such purposes, in India and in Spain, a watering of 10,000 cubic feet is ample, either for pasture or arable land. One such watering represents a depth of ·23 feet over an acre, and is equivalent to a continuous supply throughout the year of ·000317 cubic feet per second.

"In a hot climate, or with a drier soil, a greater number of waterings might be required, but not a larger supply at each watering."

From the foregoing tables the number of waterings appear to be forty-six and twenty-three in the year for meadow and arable land respectively on sandy soils, and thirty and fifteen on clayey soils. "Leaving out of consideration the fact that these waterings are a half and three-quarters larger than would be requisite in India or Spain, their number seems excessive.

"In India the number of waterings prescribed on the Nageenah Canal, North-west Provinces, is thus:—

For fruit-gardens	8 per annum.
,, hemp	5 per crop.
,, rice, indigo, sugar, tobacco, grass, herbs	4 ,,
,, cotton, wheat, barley, grains, and pulses	3 ,,

"In Spain the number of waterings in the year generally necessary are :—

For corn, flax, potatoes, olives, and pines	6	waterings.
,, meadows and artificial grasses	8	,,
,, garden produce	20	,,

and these by no means show the highest duty obtained by water in Spain ; for gardens on clayey soils are irrigated with ·0014 cubic feet per second per acre through the year, and only require double or treble that amount, say ·004 cubic feet per second, in very dry seasons ; whereas the watering of garden land with twenty irrigations, as above, requires ·012 cubic feet." *

The assessment of the water rate is made in three different ways :

1. By fixed outlet, or by measurement.†

"The small channel of supply being constantly full and of a certain section, may be charged at so much per square inch or square foot of section, independently of the amount of pressure, for a certain time, as the day of 24 hours. This has been adopted in Italy, but has not been found to work well.

"A further development of this method is to measure by module all the water as distributed, a mode more

* Jackson, "Hydraulic Manual."

† There are three methods of measuring the discharge of a stream:—

1. By weir-gauges (for small streams) with notch orifice. The right-angled triangular notch is the best form of orifice, as it measures large and small quantities with equal precision, and has a sensibly constant co-efficient of construction. When orifices are wholly immersed, round or square holes are the best, because their co-efficients of construction vary less than those of oblong holes.
2. By current meters, in which the rotations of a fan driven by the current are registered by wheel-work.
3. By calculation, from the dimensions and declivity. Weeds have been known to increase friction tenfold.

likely to be adopted at present, now that modules are less expensive and more effective than formerly.

"2. By the area of land irrigated, or by crop.

"3. Water distribution by rotation.

"An irrigating channel of fixed dimensions, giving a constant fixed discharge, passes through the lands of several proprietors; a period of rotation is fixed for this channel, from 6 to 16 days, according to the crops. Each landowner can then have the whole volume of the channel turned on to his land once in the total period of rotation for a certain number of hours, as from 2 to 40, or 50, according to the amount of land he owns.

"For example. Let 10 days be the period of rotation, and let him require 12 hours' supply once in that period. His name is placed on the list, say sixth, and he gets his supply turned on at a fixed hour, and turned off at a fixed hour also. If the channel gives 20 cubic feet per section, his amount of water is equivalent to a continuous discharge of—

$$\frac{20 \times 12}{240} = 1 \text{ cubic foot per second.}$$

In this way intermittent supplies admit of mutual comparison." *

* Jackson, "Hydraulic Manual."

CHAPTER V.

MODES OF IRRIGATING.

THE mode of laying on the water must depend on the configuration of the surface, and on whether the land is under grass or tillage.

The systems that deserve to be specifically noticed are —Bed-work Irrigation; Catch-work Irrigation; Sub-Irrigation; Side-Irrigation with open Drains; Pipe and Hose Irrigation; Irrigation by Surface Pipes; Flooding, or Swamp Irrigation; Sewage Irrigation; and Warping. The three last-mentioned systems will be dealt with separately, however, in future chapters. Water-drills, carts, sprinkling-pots, and syringes ought also to be mentioned.

Bed-work Irrigation.—This system is only suitable to grass lands of a level or nearly level surface. It consists in laying out the ground into sloping beds or ridges, 10 or 12 yards wide, according to the nature of the soil, having their upper ends lying in a gentle slope from one end to the other of the meadow (Fig. 1). The main feeder or conductor is taken out of the river or canal, as the case may be, at a sufficient level to command the upper ends of these ridges. From this conductor the water is carried by small trenches or irrigating channels (*a*) along the tops of the ridges. These irrigating channels, or distributors, are made 4 or 5

inches deep, and 12 inches or more wide at their junction with the main conductor, the width gradually lessening as they recede from it. When the distributors are filled, the water overflows on both sides, and is taken up by the furrows or drains (*b*) which occupy the hollows between the ridges. The water thus collected by the furrow drains is received by the main drain, which conveys it back to the river from which it was taken, or carries it on to water other meadows, or other parts of the same meadow below. The main drain is, of course, cut across the lower ends of the beds, and requires to be made nearly as large as the conductor. Fig. 2 shows a section of the bed-work.

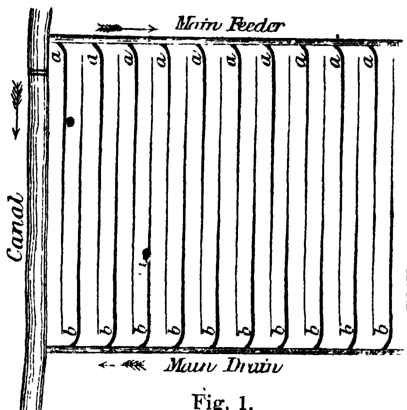


Fig. 1.



Fig. 2.

The dimensions and inclination of the conductor and distributors should be so regulated to the water-supply that the beds can be wholly laid under water to the depth of about 1 inch. The conductor must be tapered off towards its farther end, in order that the diminished supply of water may still overflow; and the distributors must likewise be made to taper towards their farther

extremity, both for the purpose of retarding the velocity of the water and of preserving a continuous overflow along their whole length. On the other hand, the small drains and the main drain should gradually widen towards their lower extremity. The distributors and small drains are usually made from 12 to 18 inches wide at their junction, and from 6 to 9 inches at their ends. The inclination of the ridge itself should afford a fall of 1 in 500, and the inclination of the sides of the ridges may vary from 1 in 100 to 1 in 1000, according to the retentive power of the soil. Ridges should not be more than 100 yards long.

Few if any meadows are now laid out on the bed-work system, as it is only applicable to flat meadows, which can generally be rendered productive without the sacrifice of land which is involved in throwing them up in ridge and furrow form, and cannot be carried out without very considerable expense, the cost of the work often ranging from £10 to £20 per acre.

Louden gives an example of a very complete piece of bed-work irrigation (Fig. 3), which was formed for the Duke of Bedford, by Smith, at Priestley, on a meadow of irregular surface. The water is supplied from a brook (*a*), to a main feeder, with various ramifications (*b b*); the surface is formed into ridges (*c c*), over which the water flows, and is carried off by the drains (*d d*) to the main drains (*e e*), and to the brook at different places (*f f*). There are bridges (*g*) over the main feeders, small arches over the main discharging drains (*h*), and three hatches (*i*).

Formation of Water Meadows on the Bed-work System.—Sir John Sinclair gives the following particulars on this point: "The water being carried with a proper fall—that is, with from 1 inch of fall in 20 yards

to 1 in 30 yards, according to the weight and velocity of the water above the mouth of the conductor—to

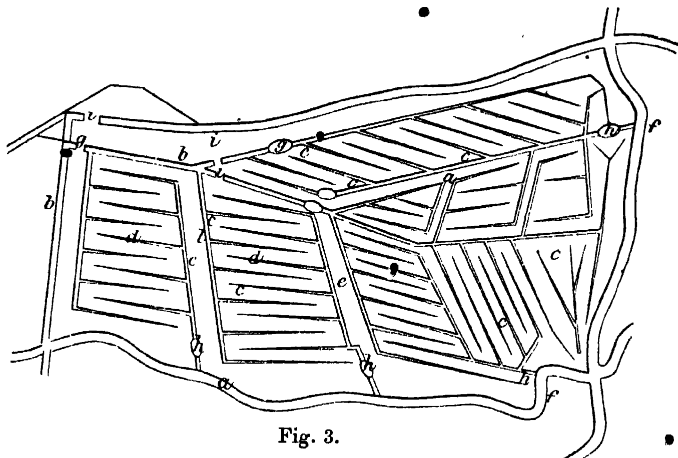


Fig. 3.

the highest part of the meadow, the next object is, to make the conductor large enough to receive all the water that the stream contains if there is land enough to use it. If there is a great fall from the wear or dam (sluice) to where the meadow is to begin, it

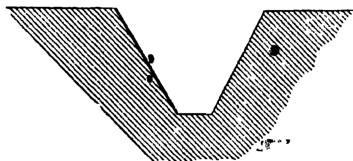


Fig. 4.

(the conductor) may be made comparatively deep and narrow (Fig. 4); but on nearly level ground it must be made shallower and wider (Fig. 5), as it is only near



Fig. 5.

the top of the stream that the water has any draught. It

is of no use to make the bottom of the conductor deeper than the feeder will draw the water out of it; neither is it of any use to make the bottom of the feeder any deeper than the last floating gutter (or irrigating channel) will draw it off. . . . . In forming the master-feeder it will be necessary to ascertain the breadth and depth that will hold all the water that the conductor brings to it, and thence to the end of the feeder, where the last floating gutter goes out. Its breadth should be diminished all the way; and whatever its breadth may be at the beginning, it should end about 2 feet in breadth where the last floating gutter goes off.

"If the ridges or beds be 10 or 12 yards wide, and about 100 yards long, with 6 or 8 inches of fall, the breadth of the floating gutters should be about 18 inches at the head, or 2 feet, according to the length of the gutter, and about 6 inches at the lower end of the ridge. This diminution of the gutter serves to force the water out over the sides of the beds; and as a part of the water is always going out of the gutter, it is always growing less, and consequently does not require so much room to hold it. The stuff that is taken out of the feeder should be laid smoothly along its sides, with a slope outwardly, and raised about 6 inches above the surface of the ground; and in crossing ridges the hollows must be filled up with superfluous stuff from the high places or out of the drains, so that the top of the banks of the feeder may represent a straight horizontal line, and keep the water above the surface of the ground, which is necessary to make it flow down and over the sides of the floating gutters with proper effect.

"In making the floating gutters, after both sides of one are cut with a spade, by a line, then cut again with a

spade down the inside of your lines on both sides, beginning at the head about 5 or 6 inches from your line, so diminishing all the way down to the end, and pointing the edge of your spade so as to make it intersect your outside cut. When both sides are done, the land in the breadth of the gutter will be divided into three strips, the outside of which will be loose, and will turn out whole in triangular furrows, which form the sides of the gutters and keep up the water above the surface of the ground. After the sides are cut, there will remain a fast strip in the middle, which must be taken out and laid in equal portions on the outsides of the said furrows, or into the lowest places. In taking out the fast strip, it is best to leave here and there a piece unremoved, which serves for stops and saves putting in afterwards. These stops will be wanted more or fewer in number, according as there is much or little descent in the floating gutters. When there is nothing left in for stops as above, the defect must be supplied by putting in boards or sods to check and raise the water to the height you want it. Without stops the water would all flow to the lowest end of your work, and there run out too deep; while the higher parts of the meadow would remain dry. Notches are commonly used at first in letting out the water from the feeders and gutters over the beds; but when the sides become older and firmer, it may be made to flow over them. The breadth of the beds should not exceed 10 or 12 yards; but if less than 8 yards, it is best, in general, to put two into one, either with the spade or the plough. The length of a division of floating gutters should never exceed 100 yards in the ridges or beds; because, if they are too long, it makes the water more difficult to regulate, and, if the stream be

fluctuating when the water falls in, the upper parts of the beds will be dry. All floating is the better of a descent, from the crown of the ridge to the furrow, of from 1 inch in a yard to 2 inches. This must be attended to if the land is to be formed into beds with the spade or the plough; but where it is in proper ridges before, they may be taken as they are, be the descent less or greater than as above.

"At the lower end of the meadow, and indeed at the end of every set of beds, there must be a main drain, and betwixt every two gutters there must be a small drain, to receive the water that flows over the beds and carry it into the main drain. These small drains must be parallel with and reverse in their dimensions to the floating gutters, least at the upper and largest at the lowest end; whereas the gutters are largest at the upper end and smallest at the lower. These small drains, if in a dry soil, will do 6 inches wide at the head and 18 inches at their junction with the main drain. The stuff that is taken out of them is always wanted to make up hollows, or to make up the banks of the feeders, to carry them through low places to higher ground; but wherever it is put it must be properly smoothed to let the water flow regularly over it.

"When a meadow is large and the surface not all upon one section, but has high and low places in it, more feeders must be made, and more cross or master drains. Sometimes it happens that a feeder must cross a drain in carrying the water from one eminence to another through a hollow: in this case a trunk must be made with boards of the size of your drain and placed in it, and the feeder carried over it. The trunk must be as much longer than the width of the feeder as will be sufficient to give room for proper banks to the

feeder, otherwise the weight of the water will force them out. If the feeder be small and the drain large, it will be cheaper to make the trunk or spout correspond with the size of the feeder, and carry the water over the drain in it. Hatches or sluices (one or more according to the size of the feeders) are always necessary in the mouths of them, for excluding or admitting the water at pleasure, and also for changing it when the meadow is divided into divisions."

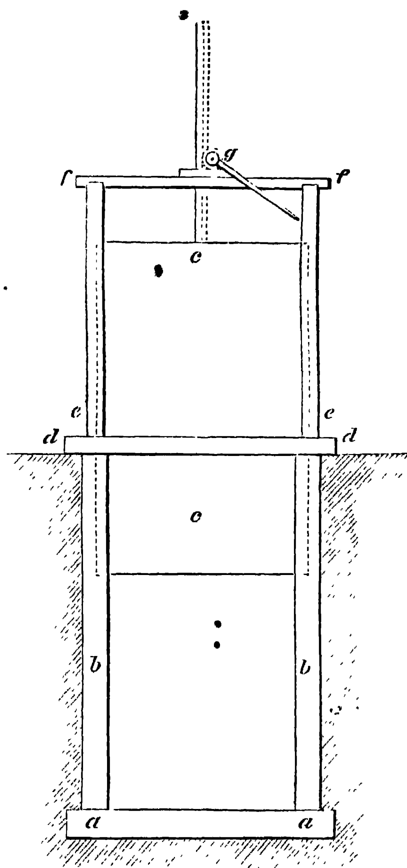


Fig. 6.

Various kinds of sluices are employed to take in water from the river or canal, &c., to the main feeder. Fig. 6 represents a good construction by Mr. R. Scott Burn. "*a a* is the stone sill, *b b* the side quoins in which the grooves are cut, and in which the wood or sheet-iron

sluice-door (*c*) slides up and down. The stone flat (*d d*) supports the wooden uprights (*e e*), carrying the cross-bar (*f f*) in which the pedestal of the toothed wheel (*g*) is fixed, this gearing with the rack of the stem of sluice door."

Wooden "stops" for the small channels are seldom used, a turf or a spadeful of earth serving the purpose. Fig. 7, however, illustrates a wooden stop made of "two boards (*a a*) joined together, but kept separate by pieces at the end into which the sluice board (*f f*) is passed, being lifted up by the hand-hole (*g*), and kept apart at any point by the wedge (*h*). The aperture to allow the water to flow through is *b c d e*, the edge (*c e*) being on a level with the bottom of the channel."

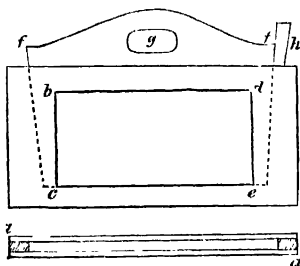


Fig. 7.

Catch-work Irrigation.—This differs materially from the bed-work system. It can be applied to sloping and undulating surfaces as easily as to level lands, and to lands under tillage as well as under grass; it sacrifices no land and costs very little, and it is quite as effective as the more expensive bed-work.

The feeder or conductor, formed as before, is led along the highest side of the field, and a spring or small stream directed into it is made to overflow the side by the end of the ditch being dammed up; but as the water would soon cease to flow equally for any great length, and would wash the soil away in places, small parallel gutters or trenches are cut, at distances of 20 or 30 feet, to catch the water again (Fig. 8); and each of these

being likewise stopped at the end, lets the water over its side, and distributes it until it is caught by the next; and so on over all the intermediate beds to the main drain at the bottom of the meadow. Fig. 9 represents a section of this system. The cross gutters must be laid out perfectly level, and of course on most lands will be winding; and these again are sometimes crossed by feeders running from the conductor to the lowest side of the field, thus forming a kind of check work.

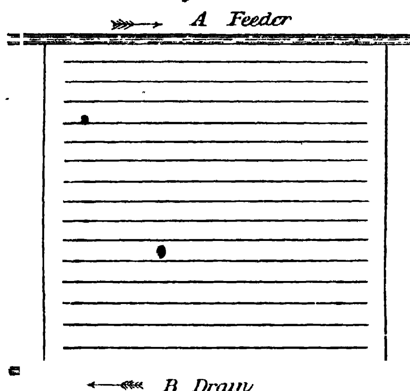


Fig. 8.

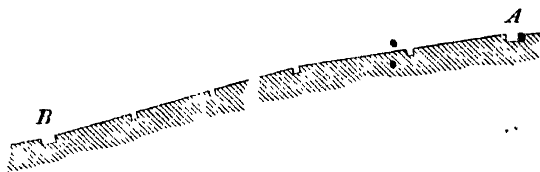


Fig. 9.

Fig. 10 shows the latter plan of catch-work, in which "the channel of supply at *a a* delivers the water to the gutters (*c c*), which again deliver it to the branch gutters (*c*). The water flowing from these over the surface of the land reaches the lowest level, where the catch-drains (*b b*) are placed; these deliver the water to the channel (*b b*) which carries it finally off."

The cross gutters are rapidly thrown out by the plough, and may be renewed every year if necessary on grass as well as on ploughed land; while the principal

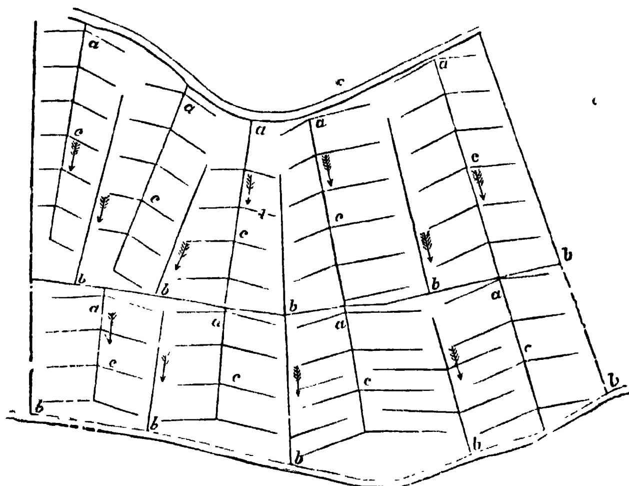


Fig. 10.

feeders and drains remain, and at most only require to be repaired and filled with water.

As to other modes of watering in catch-work, the diagonal system is perhaps the most effective.

In all cases when the water seems to have sunk, it should be taken up again by opening a new trench for it, in order to collect or *catch* it, for diffusing it over another surface.

In Pennsylvania, Dr. Edwards tells us, "hills so steep as not to be arable are watered, and produce greater quantities of grass than flat grounds, without ever having had a forkful of manure put upon them, and are now richer than they were thirty years ago,

after having had two crops of hay, and sometimes three, annually taken from them."

He describes the American plan of watering uplands as follows: "The first object, certainly, is to secure a complete command of the spring or stream to be made use of. For that purpose a drain must be made as near the source as the circumstances of the case may require, and the water must be then brought on the same level, by a canal or ditch all along the side of the hill.

"The spirit-level is made use of for the purpose of finding out the proper line to conduct the water. When the true level is found and the canal made, the water should be turned into it, which, if stopped either at the far end or any part of it, with a gate being shut down, it will flow over and irrigate the land below; or the canal may be made so high on the bank that the lower side of it shall be about 6 inches above the water when standing on a level with its source; and it is then let out by small gutters, about 10 or 15 feet from each other, which are spread a little below by arms each way, so as to meet one another in such a manner as to throw all the ground under water. By this mode, if there be plenty of water, the whole ground may be irrigated; but if it be scanty, half of these gutters may be stopped by small sods one day, or two days if necessary, and the other half afterwards, when the first are taken up; so that the whole can be flooded alternately every other day; a practice preferred by some, even where the water is abundant.

"At a distance of near two rods below the first canal another is made, to receive all the water that has flowed over the ground between the two, and again turned out as above;" repeating the process till the lowest level of the field is reached.

"The whole surface of the land to be irrigated should be made so fair and smooth that where the water is turned out to produce its great effect, there should not, to have it complete, be a hollow or hillock, in which a drop of water can stand, or over which it cannot flow."

Sub-Irrigation.—This consists in saturating a soil with water from below instead of from the surface, and is effected by a system of subsoil pipes, which, proceeding from a main conduit or other supply, can be charged with water at pleasure. In some parts of the United States perforated pipes are used for the purpose, but the common drain-pipe answers quite as well. The usual plan is to surround the field with an open drain or main, and intersect it by covered drains communicating with this main. If the field is level, nothing more is necessary than to fill the main, and keep it full till the ground is sufficiently soaked. The water escapes through the joints of the pipes, and rises into the superincumbent soil, by pressure and by capillary attraction, to as great a height as the water is standing in the main drain. In this manner water may be given to the roots of plants in dry weather; and when the saturation is complete the whole of the water may be removed at will by opening the drain outlets and reestablishing free drainage. When the land slopes, the lower ends of the drains must be closely stopped, and the water admitted only into the main on the upper side; this main being kept full till the land is soaked, after which the mouths of the lower drains are opened to carry off the superfluous water.

It is claimed that this method produces all the good effects of surface irrigation with a much less quantity of water, while the surface soil does not bake. For lands under tillage the plan is an excellent one, par-

ticularly on porous soils. Of course, by this method, no deposit from the water is left on the surface of the land. It is chiefly adopted on fens and drained morasses, which are apt to become parched in summer; but it would be very valuable for all light soils under green crop in seasons of drought.

Side-Irrigation with Open Drains.—On this system the field is intersected by open drains, at the usual distances, which communicate with the open ditches or drainage canals. When the land is to be irrigated, water is let into the ditches, and thence to the small drains, till it rises to or near the level of the surface;

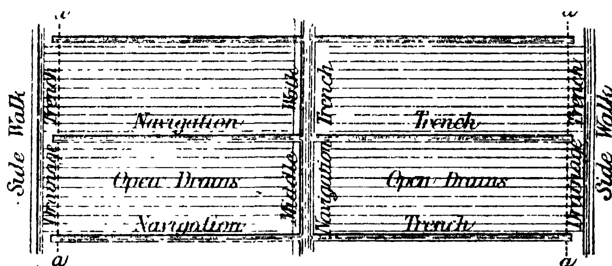


Fig. 11.

and the ground is laid dry again by opening the sluice valves, and emptying the side ditches. The Demerara field system (Fig. 11) offers unusual facilities for this method of irrigation, in the simplest form. By stopping up the small drains at *a a* near their junction with the side-line draining trench, and then filling the navigation trenches to overflowing with fresh water, the open drains become collectors, and the water can be made to rise in them to any desirable height, swamping the entire ground surface if necessary. When the watering is complete, the pressure of water from the navigation trenches is withdrawn, the stoppages

in the drain mouths are removed, and the surplus water is free to escape to the draining trench. Where a sandy or gravelly soil rests on a retentive subsoil, this mode of watering may take place without drains by filling to the brim and keeping full for several days surrounding trenches; but the beds or fields between the trenches must not be too great.

Irrigating by Pipes and Hose.—"There are many cases in which the methods of surface irrigation pre-



Fig. 12.

viously described are unsuitable. Where the surfaces are irregular, where the crops are changed several times in a season, where the ground is under biennial or perennial crops, and furrows cannot be maintained, or where the ground is too valuable to be occupied by furrows or water channels; these and other conditions will be favourable to one or other of the following plans. The first to be treated of is that of underground pipes and stationary hydrants, from which

water may be distributed under pressure through india-rubber hose and sprinklers (Fig. 12). An elevated reservoir is provided, from which an iron pipe, having a capacity equal to an inch and a half in area for each acre to be irrigated, is carried along the centre of the garden. A 2-inch pipe will be required for two acres, a 3-inch one for four acres, and a 4-inch one for eight acres. From this pipe others are carried at right angles 200 feet apart to within 100 feet of the boundary upon each side. The pipes are laid a foot beneath the surface, or so far that they can never be disturbed by the plough. Upon the lateral pipes, which should be at least an inch and a half in diameter, so that the flow shall not be unduly interrupted by friction, upright pipes, or hydrants, are attached, which project at least three inches above the surface of the ground. These are about 200 feet apart. They are furnished with valves, which operate by means of a square head and a key. Each one is fitted with a cap which screws on or off, and which is attached to the hydrant by a short chain for its preservation. When this cap is unscrewed, a section joint affixed to the end of the hose may be screwed in its place."

"When this apparatus is in operation, the water descending from the elevated tank or reservoir passes through the pipes and the hose, and escapes with some degree of force, depending upon the height of the head, through a flattened nozzle, which scatters it in a thin sheet or broken shower. With this apparatus one man may water copiously five acres of ground in a day or night. Each hydrant being the centre of a plot 200 feet square, serves to irrigate, with 100 feet of hose, very nearly or perhaps one acre of ground. To irrigate five acres in ten hours would give an hour and a

half to each plot, and amply sufficient for an active man to get around a plot of 200 by 200 feet."*

An improved nozzle for shower irrigation is manu-

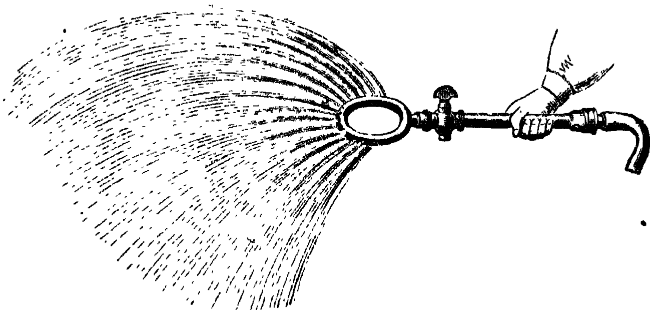


Fig. 13.

factured by Messrs. J. Warner & Sons, London, and is represented in Fig. 13.

Irrigation by Surface Pipes.—By this method the distributing pipes are laid upon the surface of the

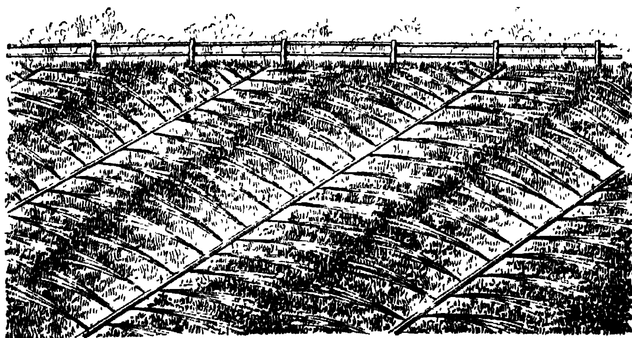


Fig. 14.

ground, and are perforated in such a manner that the water is discharged in a shower of spray upon the

* Stewart's "Irrigation for the Farm, Garden, and Orchard."

ground (Fig. 14). The distance the pipes are laid apart may be 24 feet or more, but this will depend upon the pressure and force with which the water is discharged. The disadvantage of this system is its first cost; but once the apparatus is provided it can be put in operation with little expense, all that is required being the turning on and off of the water at intervals.

Water-Drills, Water-Carts, Garden-Engines, and Syringes.—The water-drill is now in great request for sowing turnip and mangel seeds in dry weather. As these crops are put in at one of the driest periods of the year, its use insures a rapid and healthy braird of the young plants. The drill is a common turnip and manure drill, with the manure-barrel fitted for carrying water and for distributing it in the rows immediately underneath the seed. The quantity of water can be regulated, and either pure water or manure water may be used. In the latter case superphosphate, or guano, is dissolved in water, and the mixture used at the ordinary rate for dry manure per acre. The water-cart is sometimes used in dry weather for watering drilled crops after they are started into growth. Two forms of improved water-carts are shown in Figs. 15 and 16. The former is manufactured by Messrs. Colman & Morton, Chelmsford; the latter by Messrs. James & Son, Cheltenham. Each of these carts is fitted with a short hose for dropping into the tank or well, &c., and a pump for filling it with ease and rapidity. Garden-engines and Syringes, though very

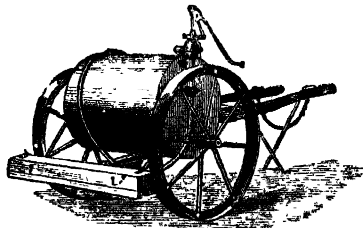


Fig. 15.

serviceable in their place, are of course only useful where a few plants or beds of ground are to be dealt with. Fig. 17 shows a special syringe, manufactured

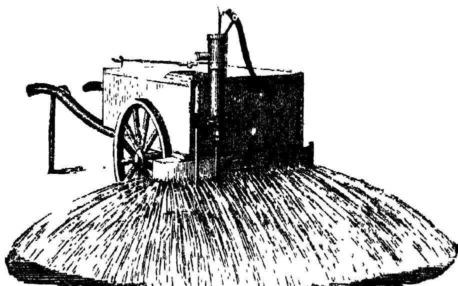


Fig. 16.

by J. Warner & Sons, for washing hop vines. By means of this instrument all parts of the vine are easily

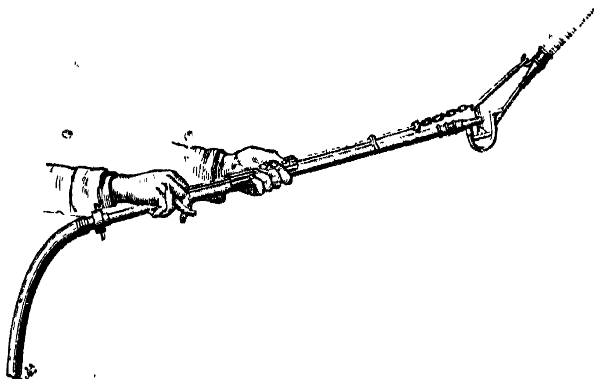


Fig. 17.

reached, and it effects great saving in the washing mixture.

CHAPTER VI.

MANAGEMENT OF IRRIGATED GRASS LANDS.

Application of Water.—On English water-meadows, as a rule, the irrigating season begins at the end of October, and is continued till about the first week in April. The usual plan is to keep the land flooded to a depth of about 2 inches during the months of November, December, and January, for a fortnight or three weeks at a time, and then let the water drain off from it for a week or so before flooding again. In February and March the waterings are gradually shortened to eight days at a time. At the beginning of April the land is left dry, and in May the grass crop is cut.

In November the water is used very plentifully for the first three weeks, after which it is taken off for a week, or changed to another part of the meadow. When the grass turns dark the water should be taken off. A standard work on farming directs that it should be taken off on occurrence of frost. The true rule, however, is not to take it off nor to lay it on in a frost;—not to take it off, because the water, freezing on the ground, forms a coat of ice which protects the grass; not to lay it on, because the ground, being already frozen, can be no longer protected.

In December and January the chief care consists in keeping the land sheltered by water from the severity

of frosty nights. In very frosty weather it is better to take off the water from the meadows altogether if it is severe, and likely to continue long; but this must be done at the beginning of the frost; if this has not been done the water should be allowed to remain on during the continuance of the frost. The danger from frost is, that if ice forms under and around the roots of the grasses the plants may be thrown out by the expansion of the water. This can only be prevented by keeping the grass protected by water, or else making the land so thoroughly dry that no injury will result from frosty weather. In spring the young and tender shoots of grass are easily nipped and destroyed by frost, if these precautions are neglected.

In February the management is much the same as in January, only, if the weather is mild, the water will require to be taken off or changed more frequently. If the water remains on for many days about the end of this month, in bright weather, a white scum arises, very destructive to the grass; and if the land is exposed, without water, to severe frosty nights, the greater part of the grass will be killed. The only way to avoid this is to take the water off early in the morning, and turn it over at night; or, if the day be very dry, keep the water off altogether during the frost, for it is only when the grass is wet that the frost has a pernicious effect.

In March, as vegetation sets in, care must be taken to shelter the young grass as much as possible. When the water is changed or removed, a mild day must be chosen for it; and it is best to do it in the morning, that the ground may dry before night, and be able to withstand a frost the better. In this month scum on the water must be guarded against; but,

instead of changing the water at stated times, it should be done according to the weather, always taking advantage of a fine day, which may vary the time from a week to once in a few days, less or more.

If the meadows are to be spring-fed, the watering ceases about the middle of March, or the first week in April at latest. Early in May, when the spring-feed is eaten off, the water is used for a few days before laying up the meadows for mowing; and again when the hay crop is carried off.

The watering of grass lands, other than water-meadows, is very simple, as it is seldom practicable to lay them under water, and they can only be irrigated by flowing the water over them. This is done at intervals, which will be determined by the weather more than anything else. As the grass is never completely covered, the irrigation cannot be carried on in frosty weather; so that on high lands, and, indeed, on most catch-work meadows, where the ground slopes or is undulating, it is impracticable to irrigate during winter, and watering has to be delayed until the spring frosts are over. This puts off the spring watering until April or May; after which, however, there is still time to grow a crop of hay. Any attempt to irrigate upland meadows in winter, and to pasture them in early spring, would but injure the meadow by means of frost, and at the same time rot the sheep.

Spring-Feeding.—The great value of water-meadows consists in the early spring feed which they afford, between "hay and grass," by which the farmer is enabled to breed early lambs. As soon as the lambs are able to travel with the ewes, about the middle of March or the beginning of April, the flock is put into

the water-meadows. Care is taken to make them as dry as possible for some days before the sheep begin to feed them, and, on account of the quickness of the grass, it is not usual to allow the ewes and lambs to go into them with empty stomachs, nor before the morning dew is gone. The general hours of feeding are from ten or eleven in the morning till four or five in the afternoon, when the sheep are taken off and folded on swedes or mangel for the night, or else put into a dry meadow or pasture where a few swedes or mangel and some box-feeding can be supplied to them. The grass on the water-meadows is daily hurdled out in portions, according to the number of sheep, to prevent their trampling it down; but a few spaces are left in the hurdles for the lambs to get through and feed forward in the rich grass. One acre of good grass will be sufficient to last five hundred couples a day. The great object is to make the water-grass last till the winter rye, barley, and forward vetches, &c., come in for feed; the meadow is then laid up for hay.

Late spring pasturing on meadows is objectionable, as it always lessens the hay crop, and the harm done is usually in proportion to the dryness of the meadow. Water-meadows may be fed during April, and then be laid up for hay; but dry meadows should not be spring-fed at all.

Laying-up Meadows.—In regard to the time of laying-up the meadows, quaint old Tusser says:—

> "Spare meadow at Gregory, marshes at Paske,
> For feare of drie summer, no longer time aske;
> Then hedge them and ditch them, bestowe thereon pence,
> Corn, meadow, and pasture aske always good sense."

St. Gregory is the 12th of March; Paske is Easter; and Tusser's meaning evidently is that marsh meadows may be grazed a month longer in spring than dry

meadows, and still yield a good crop of hay, however dry the summer.

After spring-feeding, before any water is given, the meadows should be put into the best condition for laying up. The ditches and furrows should be examined and repaired, the drains cleared, and all rubbish taken off the surface. Any inequalities of the surface should also be remedied with the spade, first taking off the turf, and then replacing it and beating it firmly down. The meadows are next bush and chain harrowed; any rubbish brought up is picked off, and then the ground is rolled with a heavy roller. If any grass seeds are to be sown, it may be done previous to harrowing. Farmyard manure, if given at all, should be applied when the hay crop comes off, and only in a well-rotted state. Artificial fertilizers will rarely be necessary; but if given at all it may be in the form of a top-dressing, after laying-up for mowing.

Cutting.—From the great succulency of the plants produced in water-meadows, the converting of them into hay requires particular attention. It is desirable that the grass should be ready to cut early in the season, not later than the end of June or the beginning of July, when the weather is likely to be favourable for hay-making; and to this end the meadows should be laid up early. It is not advisable, however, to cut the grass of water-meadows too soon, or before it approaches ripeness, as there is then more loss of weight and substance in the making. The best time to mow is when the bulk of the grasses are in flower, unless in cases where the grass has fallen down, and would spoil if it remained uncut. Attention, however, must be paid to the state of those plants which constitute the bulk of the crop, and if the rough-stalked meadow-

grass, the scented vernal grass, the soft meadow-grass, are the most abundant, the grass may be cut earlier. In taking off the grass, carts and waggons should be used very carefully upon the meadows, lest ruts may be cut to the injury of the surface. Roadways across the meadows, from point to point, should be previously laid out, using wooden culverts where the roads cross the irrigating ditches or drains.

Repairs.—In addition to what is done at the time of laying-up for mowing, a water-meadow will require some annual repairs in autumn. Thus, in the month of October, when the after-math is fed off, the banks of the feeders must be repaired where they have been trodden down by the sheep or cattle, and the sand or mud that lodges in any of them thrown out. The sides of the feeders and gutters may be trimmed with a large sharp reaping-hook, and the bottoms may get a light shovelling out. The clearings may be trodden down smoothly at the back of the gutters, or put into hollow places, &c.; but it must always be observed not to clean the floating gutters so hard at the lower end as at the upper, that the diminishing proportion of their size may not be destroyed.

Water-Meadow Grasses.—These plants, Dr. Singer observes, ought to be perennial, as it can never be intended that the meadow should soon be broken up. In America, timothy, or meadow cat's-tail (*Phleum pratense*), is greatly in favour for water-meadows; and it is remarked that white clover bears drowning better than any other plant of that nature, although it does not yield the bulk which is desirable in a hay crop. By careful management, re-seeding, and manuring, timothy and clover may be retained in a water-meadow; but many of the following plants are but slightly inferior

to them, and, as they grow more abundantly and constantly, are better adapted to this culture:—(1) perennial red clover, or cow-grass, which naturally prospers where the soil contains a due proportion of marl or lime; (2) soft meadow-grass (*Holcus lanatus*), which thrives well in any soft soil, especially if it be also watered; (3) rough-stalked meadow-grass (*Poa trivialis*), which delights in a soil between loam and bog, possessed likewise of a degree of moisture; (4) crested dog's-tail (*Cynosurus cristatus*), which thrives well in watered loams; (5) sweet-scented vernal grass (*Anthoxanthum odoratum*), which hardly fails in any water-meadow where it has been once established, and whilst it adds to the bulk and weight of hay, it likewise communicates, if made in dry weather, the sweetest odour to the whole crop; (6) bent grasses, in particular white-bent (*Agrostis alba*), and creeping-bent (*Agrostis stolonifera*), or the famous *fiorin*, which some recommend in preference to every other, for water-meadows, long and fully irrigated.

The nature of the herbage upon an irrigated meadow, remarks Mr. Stewart, depends greatly upon the skill with which the irrigation is managed. If water is used in excess, the more valuable grasses disappear and inferior ones take their place—such as couch grass, the spear grasses, and other coarse species.

Italian rye-grass (*Lolium Italicum*) is extensively grown under irrigation in England and elsewhere, and yields repeated heavy cuttings of forage for soiling. It is the chief grass grown upon the Italian water-meadows, upon which it yields an aggregate cutting of forty tons and upwards of green fodder per acre yearly.

CHAPTER VII.

MANAGEMENT OF IRRIGATED ARABLE LANDS.

THE irrigating furrows upon cultivated land can seldom be permanent, except in vineyards and the like, where there is not a constant change of crop going on. In such grounds a system of irrigation may be laid out as complete as in the case of a water-meadow, as the work will be permanent in character, and the first outlay will be the last, if the work is properly done. Generally, however, the irrigating channels on arable land will be destroyed at every ploughing, and must be re-made for every crop.

The watering of arable land and crops, though uncommon with us, is universal in warm countries, and even in Southern France, Spain, and Italy. In many cases the crop is grown in drills, and the water is simply introduced in the furrow between each row. In this mode of irrigation, no collecting drains are required, as the whole of the water laid on is absorbed by the soil. The principal expense of the operation is that of preparing the lands by throwing the surface into a proper level or levels. The main conductor carries the water to the higher part of the field, and the rest is easy. A side conductor should be formed along the entire length of the field; so that the field can be watered in sections if wished, by closing the supply-channel at any desired point.

With crops under flat culture, such as wheat or barley, there are other plans available. If the ground slopes, the ordinary catch-work system may be adopted, drawing with the plough light furrows from the main conductor at the top of the field, parallel and horizontal to it, or in diagonal or diamond form, or otherwise, according to the contour of the surface. On level ground the land may be ploughed into beds, and the water introduced in furrows during the growth of the crop: this may be done either by a system of side-irrigation, the soil absorbing the water from the ditches, or by regular flooding.

"In the flat plains of the Rioja," Mr. Roberts * tells us, "a small mound or embankment of clay is formed around each field; and when irrigation is required, the water is admitted from some of the minor channels, of which there is a network on every farm, through an opening in the bank, usually placed at the corner of the field. It is then allowed to flow until the enclosure is completely covered to a depth of about three inches, when the inlet is closed with a sod, and in a few minutes the water is all absorbed by the parched soil.

"In sloping ground the Spanish farmers often level the field into a series of horizontal plots or terraces, that each inclosure may be irrigated in the manner above described. When this is not done, water is admitted at the high side of the field, and allowed to flow over it; and numerous little cuts, like plough tracks, with their corresponding mounds, are made across the enclosure, or at right angles to the direction in which the water flows, so as to check its velocity, and thus facilitate its absorption by the soil."

This system is illustrated in Figs. 18 and 19. The

* "Irrigation in Spain."

"divisions do not slope on both sides, but incline in one direction, as shown in Fig. 18, at *a b*, *a b*, *a b*; but are horizontal, in the direction of the arrows in plan,

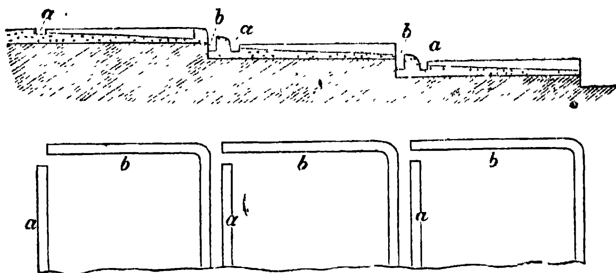


Fig. 18.

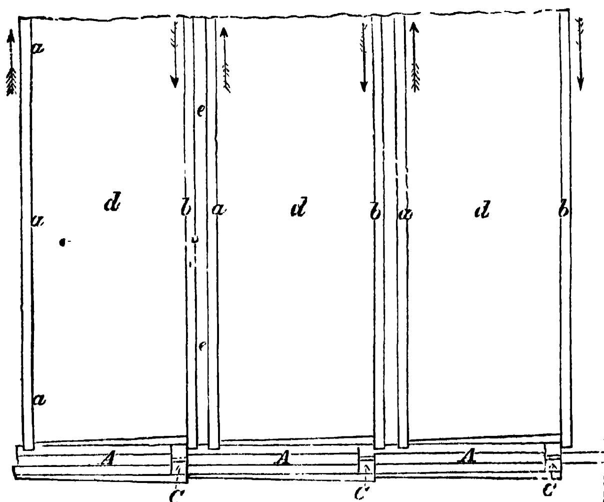


Fig. 19.

Fig. 19. The channel of supply is at *A A*, and sluices are provided at *C C C*, by which the water can be let into or kept out of the channels of distribution (*a a*),

placed at the upper side of the inclined divisions (*d d*). The channels of distribution (*a a*) are divided from each other by small embankments or ridges, as shown in section in Fig. 18. The water, after passing over the surfaces (*d d*) is taken up by the channels (*b b*)."

Mr. Roberts comments on the skilful manner in which the Spanish farmers, when irrigating their lands, conduct the water from one field to another, or from one part to another of the same field on a different level. When all the lower parts are irrigated, they construct temporary dams with the hoe, and by this means raise the level of the water so as to be able to reach the higher parts of the field. A sod or a stone serves the purpose of a hatch, or "stop-off."

Time of Watering.—The evening hours are considered the most favourable time, but this rule is nowhere universally observed.

Application of Water.—Watering should not be deferred until the ground is too dry, as it does not bake so readily afterwards. In dry weather, a moderate watering should be given before sowing or planting, and for a time afterwards the ground should only be kept moist enough to favour germination, and prevent the surface hardening. For the young growing plants, moderate, frequent waterings are best. No rule can be laid down, however, that will be generally applicable. The various field crops which may be brought under irrigation all call for special treatment, and this will vary with the district in which they are grown. The reader may here usefully refer to what has been already said on this point under the heads of crops suited to irrigation, and the number of waterings bestowed on different crops, in Chaps. III. and IV. In the case of nearly every crop, the ground must be

allowed to get occasionally dry; for even those crops which require watering most are easily injured if the water is in excess, or is allowed to remain on too long.

Cultivation.—The soil should never be stirred when wet. Tillage and cultural operations "should be timed with reference to the watering, or the watering should be so timed with reference to them, that these operations may be performed when the soil is dry and just before watering."

CHAPTER VIII.

SWAMP IRRIGATION.

SWAMP irrigation is practised more or less on the rice or paddy fields of India, Egypt, Southern Europe, and the Carolinas, and other south-eastern states in America. These crops are generally produced on tide-swamps, or other low-lying grounds, which possess no means of natural drainage; and under this system the land is commonly laid under water for weeks at a time, sometimes, indeed, from the time of sowing till the time of reaping.

The rice plant appears to adapt itself in a very wonderful manner to swamp life. Even here, however, there is doubtless no exception to the general rule, that stagnant water is injurious to the higher forms of vegetation. Where the produce of rice under such treatment appears to be as great as is to be expected from the most skilful and intelligent culture of the plant, it will probably on examination by analysis be found to compare but poorly in nutritive value with that grown under different conditions; otherwise, the presumption is that, though the water was retained on the field during the whole time of the growth of the crop, it was not really stagnant, but constantly undergoing renovation, by percolation or some other means.

Rice irrigation has been well described by the late

Robert Russell, of Kilwhiss, who visited the Carolina rice plantations in 1865, and published an interesting account of them in the *Transactions of the Highland and Agricultural Society* for 1866.

"It is on the tide-swamps of the Savannah, and the numerous other rivers in Georgia and the Carolinas," says Mr. Russell, "that the fine rice known in Europe as the Carolina rice is cultivated. The production of rice for exportation is in a large measure confined to these swamps; and it is further limited to the *fresh* tide water swamps, for where the tides are salt, or even brackish, they are unfit for irrigation.

"Though a considerable quantity of *upland rice* is raised here and there for domestic use, none of it is reckoned sufficiently good in quality for exportation. The rice which grows in the tide-swamps is of much better quality than what grows in dry cultivation. The pickles of the irrigated rice are large and equal in size, and the husk is easily separated from the kernel; whereas the upland rice, being smaller and more unequal, the sample is not only inferior, but there is a great deal more waste and labour in its preparation for market."

Another objection to the culture of rice on the dry upland soils is the great amount of manual labour which is required to keep the crop free from weeds. The lengthened period of hot weather over which its growth is extended, and particularly the circumstance of this crop, like our cereals, either being sown broadcast or in narrow drills which do not admit of horse-hoeing, tend to give great encouragement to weeds, so that its culture demands too much hand labour to be generally profitable.

"The swamps which form the rice grounds were

reclaimed by erecting embankments along the sides of the river, and preventing the overflow of the tides.

" Main canals, having sluices on their mouths, are dug from the river to the interior about 20 feet in width; and as they sometimes extend across the whole breadth of the swamp, they are more than 3 miles in length. The rice plantations are subdivided into fields of about 20 acres each. The fields have embankments raised around them, with sluices communicating with the main canal, so as they may be laid dry or under water separately, according as it may be required. Numbers of open ditches are also dug over the grounds, for the purpose of allowing the water to be more easily put on or drawn off.

" From the nature of the works which are required to reclaim the tide-swamps, and render them fit for cultivation, large capitals are invested. A great expenditure of labour is constantly required to maintain the banks in good order, to clean out the drains and canals, as well as to keep the sluices and valves in repair. It would be out of place here to give any detailed estimate of the expenses and profits of rice culture. The fact, however, of the rice grounds being higher in value than any land devoted to any other crop in the south-eastern states, is quite sufficient to attest the profitableness of rice culture. Nor is this so much to be wondered at when it is considered that the land which is capable of raising rice with advantage is comparatively limited, and has been almost all occupied for a considerable time."

In Carolina there is considerable diversity in the mode of cultivating the rice crop. "Some planters plough all the grounds every year. Those who follow this system give a light furrow in the beginning of

January, and afterwards make shallow furrows or drills, 15 inches apart, to receive the seed, which is sown broadcast at the rate of from two to three bushels per acre. A small quantity of water is then admitted for a day or two until the seed sprouts.

"The most approved and general mode of cultivating the rice fields, when free from weeds, is to sow the seed without ploughing. The stubble of the previous crop is burned over in spring, which is easily effected from the large quantity which is left at harvest. A negro then goes into the field, and makes a rut with a hoe between the rice rows of the former crop. This serves as a receptacle for the seed. Sometimes this operation is done by a small drill-plough. The seed is either covered by a rake, or the water is admitted at once, and covers it by washing down the soil.

"In all cases, the water is admitted to the fields as soon as the seed is sown, and when the young shoot appears above ground the water is drawn off. In the course of a week the crop usually receives another watering, which lasts from ten to thirty days, according to the progress which vegetation makes. This watering is chiefly useful for killing the land weeds that make their appearance as soon as the ground becomes dry. But, on the other hand, when the field is under water, aquatic weeds in their turn grow up rapidly, and, to check their growth, the field is once more laid dry, and the crop is then twice hand-hoed. By the 1st of July the rice is well advanced, and water is again admitted and allowed to remain on the fields until the crop is ripe. This usually takes place from the 1st to the 10th of September. The water is drawn off the day previous to the commencement of reaping."

In the Piedmont district, in Italy, where a great deal of rice is cultivated, the ground is first put under water, then worked up into mud, before the rice is sown broadcast over it. The water is then turned off, and the rice is left to germinate in the damp earth before being irrigated again. After this it is left almost constantly under water.*

In some of the paddy-growing districts of India the same course of puddling preparatory to sowing is followed. The land is ploughed several times while under water, and in the operation the soil is worked into a puddle, by the ploughs and by the feet of the cattle. It is then left to stagnate for a few days, after which more water is let on, and the ploughing and puddling repeated. Where vegetable manures are applied, these are trodden into the puddled soil. Before seeding the ground, the surface is smoothed by means of a heavy plank drawn by cattle.

"The rice grounds," Mr. Russell concluded, "are comparatively healthy to white men in winter, but the very reverse in summer and autumn when the crops are growing and ripening. It has been often remarked that the swamps, in their original state, along the southern rivers of the United States were by no means so deleterious to the whites as they are now, when brought under cultivation. This seems to apply, to a certain extent, to all the rich alluvial soils in the river bottoms, but is particularly applicable to the rice grounds that are irrigated by the tides. Indeed, the undrained swamps remain comparatively healthy so long as they are covered with the natural vegetation. The mere stirring of the soil, and the exposing of it to the atmospheric influences of a hot climate, invariably

* Moncrieff, "Irrigation in Southern Europe."

give rise to malaria. For this reason, the Campagna in Italy became much more unhealthy, as Dr. Arnold states, in his *Roman History*, after its drainage. There is nothing of course deleterious in the mere culture of rice ; it is the mode in which the irrigation is managed. This opinion is confirmed by the fact that the rice grounds at the mouth of the Mississippi, on which the water is not allowed to stagnate, are more healthy to the white inhabitants than either the sugar or cotton grounds of the lower Mississippi that are under dry culture. But the practice adopted on the tide-swamps of Carolina, of laying the fields dry at intervals during summer and autumn, seems to give rise to miasmata of the most deadly character to the white inhabitants, but from which the coloured are exempt. The planters, with their families, invariably leave the rice grounds during the hot season, and remain in a more healthy part of the country until the crops are harvested. And though the negroes are not liable to those diseases which are so fatal to the white inhabitants in summer, yet they do not increase in the rice districts."

The water-cress beds, which are to be found in the neighbourhood of London and all other large cities, afford a more striking example of swamp vegetation than the rice grounds we have been considering. Water-cress is grown on ground entirely under water, but the water is never altogether stagnant. It is a plant that can only be grown where there are running streams, and it also favours a limestone or chalk formation, so that in all but small artificial beds, its cultivation is limited to comparatively few localities.

In some cases it is merely allowed to grow in the natural stream, but those who make a business of growing it, increase the area by making beds at right

angles to the stream. The beds are excavated to a depth of about 8 inches, and are usually 5 feet wide, and of a length governed by the level of the land. They should be so constructed that the water from the stream may be directed into them by the use of board dams, and an overflow channel must be provided. Lime or chalk may be added to the bottom of the beds, if the soil is naturally deficient in calcareous matter.

Water-cress is naturalized in many streams, and where it occurs a supply may be secured for stocking the beds. The plant throws off roots at each joint below the surface, and if the stem be made into cuttings, each of these fragments, if set in the soil of the bed, will soon form a vigorous plant. The cuttings may be set a foot apart each way immediately before the water is let into the beds.

Where cuttings cannot be procured, the plants can be readily raised from seeds. If the seeds are sown in a box in good garden soil, and kept very moist, a supply of plants for transplanting will soon be at hand. The starting of beds of water-cress should begin in early spring.

CHAPTER IX.

SEWAGE IRRIGATION AND LIQUID MANURING.

THOUGH there are various ways of utilizing sewage, irrigation is the method which has been most extensively practised, and is the only one which demands notice in this work.

"By sewage irrigation the greatest luxuriance of growth known to English agriculture is obtained. It is adapted to all irrigable crops; but the best results are obtained with rapid-growing succulent plants, such as Lucerne or Italian rye-grass. The sewage is poured on at the rate of 400 tons per acre, equal to a thickness of 4 inches of water, during a few hours, twice in the growth of a single crop or cutting. Drainage, deep cultivation, and subsoiling should accompany the process; these tillage operations being only performed, of course, when the land has been laid-up dry. The drained and deeply-cultivated soil then passes the whole of the rich and fertilizing sewage amongst the fibrous roots of the plants, by which its substance is permeated. By this practice, a cutting of 10 to 20 tons of succulent forage is obtained as the result of not more than a month or five weeks' growth. The land is soaked twice or thrice, at intervals of a fortnight after each cutting; and four or five cuttings are thus obtained from the application of 3,000 to 12,000 tons

of sewage in the course of the year. Here, as well as in ordinary irrigation accompanied by land drainage, the result is due to an added temperature, and an addition of plant food, both of which the soil experiences; and especially to the constant motion and passage of this food beside and amongst the hungry roots of the plants which feed upon it."*

Nearly all the sewage farms in this country are laid out on the "catch-water" system, which consists in floating on large quantities of liquid sewage over a number of successive breadths of land. The objections urged against this system are—(1.) That the bulk of the water escapes by flowing off the surface, and not through the soil to the drains; and that, therefore, there is no real security that the sewage is purified at all; the fact that it flows off the surface, showing that there is more liquid applied than the land can absorb. (2.) That as the essence of the catch-water system is the pouring of sewage, and of the same particular volume of sewage, over successive areas of land, all the areas of land cannot be equally fertilized, since the sewage cannot be made to flow evenly over all the land.†

These objections apply with even more force to the "Pane-system," which is analogous to the Spanish system of irrigation by water, where rectangular and generally square plots of land are laid out perfectly flat, surrounded by a low bank, and generally on successive levels. The upper plots, in such cases, must evidently retain the whole of the suspended matter which is contained in the liquid sewage, leaving little else than clear water to flow off to the lower levels.

* "The Soil of the Farm." By John Scott and J. C. Morton.
† W. Hope "On Sewage Irrigation."

The Romford Sewage Farm, in the occupation of Mr. Hope, has been laid out in beds on the ridge-and-furrow system, each bed being 30 feet wide. The ridges are raised up in the centre, with a carriage or gutter along the ridge, over the sides of which the sewage flows, as in some water-meadows. Mr. Hope considers that this system of sewage distribution is the best of all, even for arable lands, and presents no difficulty to horse or steam cultivation; as nothing, in his opinion, is more simple than to form a low ridge, by means either of the horse or of the steam-plough.

On hill-side lands, which do not admit of irrigation by the ridge-and-furrow system, Mr. Hope adopts another plan. The hill-side land is ploughed horizontally with a "turn-wrest" plough, and then with a double-mould-board plough going in the same direction, across the hill, it is thrown into little ridges, as if for potatoes. The sewage is applied to this hill-side from a carrier running along the top, the across-hill furrows effectually preventing the liquid scouring away the earth from the plants. On this system Italian rye-grass, &c., cannot be grown, nor can cereals; but as the slope of the hill-side is far too rapid to permit of the application of any liquid by irrigation, if the surface were left smooth, this is no drawback.

At Edinburgh, where sewage irrigation has been practised with marked success for more than 100 years, about 250 acres of the Craigentinny and Lochend meadows are flooded with crude sewage, at the rate of 2,500,000 gallons every 24 hours. Of this land, 200 acres are in permanent pasture, and 50 acres in Italian rye-grass. The irrigation is carried on in the rudest and cheapest way by the owners of the land adjoining the streams of sewage; no cost having been

incurred in providing permanent carriers of any kind. The permanent grass is cut about four times in the season, and yields an aggregate crop of about 40 tons per acre. The Italian rye-grass is cut five times, and yields as much as 60 tons to the acre. The whole produce is sold, by public auction, at the beginning of April in each year, in small allotments, and realises from £20 to £40 per acre. It is eagerly bought up for cow-feeding, by dairymen in and around Edinburgh; who, in addition to the price paid for the plots, cut and remove the grass at their own expense. The annual cost of applying the sewage, and receipts for the produce, are given by Mr. Birch* as follows:—

Receipts.	£	Expenditure.	£
250 acres of grass, at an average of £30 per acre	7,500	Wages of watermen—three in summer and one in winter—and cost of cleaning out carriers .	180
		Estimated rent of land, 250 acres at £2 per acre per annum . . .	500
		Balance . . .	6,822
	£7,500		

This statement, however, is incomplete. The rent ought to be at least £5 per acre; and nothing is charged for the sewage.

"About 8 acres of the Craigentinny Farm, which is land of excellent natural quality, but too high to be irrigated by gravity, has had sewage pumped on to it by steam power. This land has received about 3,000 tons of sewage per acre in six or eight waterings during the year, and the rye-grass grown upon it has realised from £25 to £36 an acre—prices equal to those obtained at

* "On Sewage Irrigation by Farmers.'

Lochend, where four times the quantity of sewage has been applied."

It is estimated that the yield of land under sewage irrigation, with forage and root crops at least, is five-fold greater than the yield of the common agriculture of England. The quality of sewage-grown crops is also higher. Thus the proportion of cream yielded from sewage-fed grass at Croydon is stated to be about 15 per cent., whilst that obtained from ordinary pastures is only about 10 per cent. The increase of saccharine matter in sewage-grown root crops is so great as to give the crops so grown an entirely new value, in addition to the greater weight produced. On one sewage farm, Mr. E. Chadwick, C.B., tells us the rhubarb grown is so superior that it is used for making a champagne, and a wine of the character of a "still hock."

At the Annual Conference on National Water Supply, Sewage and Health, held in 1879, Mr. Colebrook, as chairman of the Reading sewage farm committee, stated the result of their experience the preceding year, particularly in the growth of mangold under irrigation. The highest weight per acre was 110 tons and the lowest 77 tons; which, he believed, was the heaviest weight ever known to have been grown. There was this peculiarity in the growth of the mangold; it was intended in the spring of the year to irrigate the land while the crop was growing, but the spring was wet and they were not able to hoe the land when they wanted, and when they were able to do so the weeds filled the trenches and they could not get the sewage on to the land while the crop was growing. He pointed out that for this reason he believed it was quite possible to overdose the land with sewage, and the result they obtained was chiefly owing to not having done so. The

crop of rye-grass was equally good. They cut six excellent crops during the year of not less than 20 tons per acre each crop, whilst the year before they had seven crops. They had rigidly excluded storm-water, and he attributed a great deal of their success to that.

At Bedford, where the sewage of 20,000 of the population is applied to 180 acres, chiefly of market-garden culture, the weights per acre of the principal crops have been as follows:—

	Tons per acre.
Italian rye-grass, per crop (sometimes cut four or five times a year)	25 to 30
Carrots	24 ,, 30
Onions	12 ,, 16
Potatoes	12 ,, 15

As much as £53 per acre has been realised with a crop of celery, and from £30 to £40 per acre with crops of onions, rhubarb, and asparagus.

In regard to the price which a farmer can afford to pay for liquid sewage, when poured over his land, it has been said that for its use to be profitable the price must not exceed ½d. per ton. At 400 tons per dressing this is equal to 16s. 8d. per acre, and as the land requires in most cases to be dressed six or eight times, that price is clearly prohibitive.

At Cheltenham, where the corporation land under sewage is not sufficient to utilise the whole of the sewage at their disposal, it is applied to neighbouring private lands at a charge of 7s. per acre for each dressing. The corporation lets its sewage-fed land at over £6 an acre, and probably not more than one-third of this rent can be charged to the sewage, as the lands are only dressed on an average about five times a year.

Sewage is best applied to land under tillage, or to grass land that will be mown. If it is not positively dangerous to graze land while under sewage

irrigation, it is at any rate objectionable, and should never be practised, unless, indeed, the land has been laid dry for a considerable time. That any ill effects are produced by feeding dairy cows or other stock on sewage-grown crops there is not the least reason to suppose. The soil itself cannot be injured by sewage nor even the crops, unless the dressing of sewage is immoderately large.

"Sewage-sickness," remarks Mr. Birch, "is a term that has become common because it sounds appropriate; but, as a matter of fact, time has no effect in making land sewage sick, for its pores may be filled, as at Edinburgh, year after year, with infinitely more dissolved manure than can be made use of by vegetation, and the land will continue to be as productive and as capable of receiving sewage as ever. A crop may, however, be ruined if it is covered with sewage, even although it may not have had enough for its manurial requirements; or land may be done more harm to than good, temporarily, by one single ill-timed dressing. Experience has proved that over-feeding with sewage has no ill effect, although land may be choked with it in one meal."

Liquid Manuring.—By this term is understood the practice, now seldom adopted except on a very small scale, of applying the drainings from the stables or from the dunghill, direct to the land in the liquid form. The use of liquid manure is no doubt very effective, but it is the extract of the dung-heap, which is afterwards of greatly diminished value. In the majority of cases, therefore, it will be found best to apply the liquid part in conjunction with the dry portion of the farmyard manure.

In order, however, that the liquid manure which

flows from the cattle-yards and from the dung-heap may not be lost, it should be collected in tanks. This will be useful whether the practice of liquid manuring is adopted or not, as in the latter case the dry manure may be made to absorb it.

If the dung-heap is made on an impervious bottom, or a small tank or vat is sunk in the ground at the lower end of the pit, the drainage from the manure will flow into it, and, by attaching a small hand-pump to the vat the liquid that there collects can be pumped back again upon the heap, whenever it is deemed desirable to moisten it.

Where liquid manuring is to be practised, the liquid in the tank may be distributed over the lands in various ways and by various means.

On a moderately large scale it will probably answer to lay down pipes above or under ground. Through these the water can be made to flow, by gravitation where practicable, or otherwise by pumping. The hose-and-jet system, which has failed in sewage irrigation from the large quantities of liquid which had then to be dealt with, will answer better here; as, although it will be found more expensive than a system of perforated surface pipes, which are self-working, the hose-and-jet system enables the manure to be directed where it is most wanted. On a smaller scale liquid-manure carts may be used. These will be found not very expensive to begin with, and will do a considerable amount of work. If the land is near by the tank, a man and a boy, with one horse and two carts, will water ten acres a day, at a cost of about a shilling an acre.

Fig. 20 is an illustration of one of Bamford's chain-pumps employed in filling a cart from the liquid-manure tank. For liquid manure and sewage the chain-pump

is the best that can be used. It requires a little more power to raise a given quantity of water than a good lift-pump; but it has other advantages. Having no

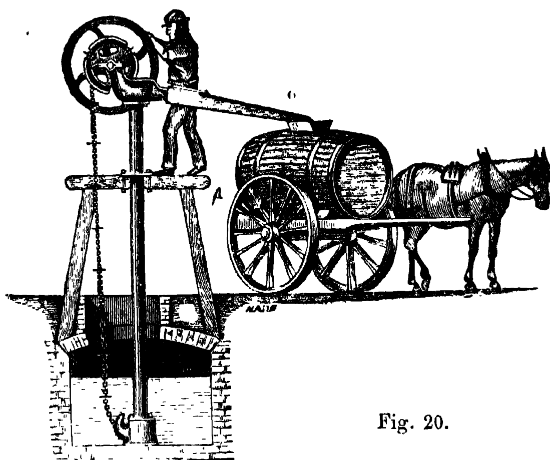


Fig. 20.

valves it is not easily choked; it seldom gets out of order; and as it is empty when out of use, it is not liable to be injured by frost.



Fig. 21.

Fig. 21 represents a distributor, manufactured by Messrs. S. Owen & Sons, London, for attaching to liquid-manure carts, with braces necessary to fix it. It can be removed at pleasure when the cart is required simply for water only.

For gardens, and other small plots of ground, a hand-barrow or garden-engine, with a small force-pump and a distributing hose and jet attached, similar to that shown in Fig. 22, will serve every purpose.

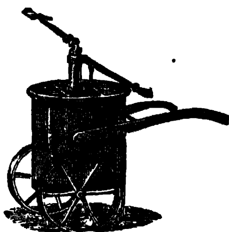


Fig. 22.

Liquid manure may be applied with great effect to all crops. The quantity to be used will depend on whether it is pure drainings from the stalls and the dung-hill, or has been diluted with rain-water. It is seldom desirable, even where possible, to use it the full strength. Diluted with, say, two-thirds water, it may be applied at the rate of 1,000 to 2,000 gallons per acre each dressing, and the dressings may be repeated as frequently as in sewage irrigation.

"Great advantage has attended the use of the water-drill for sowing turnip and mangold seed in dry seasons. By applying the artificial manures in a liquid state, the germination of the seed and the subsequent brairding can generally be relied on. In a dry climate the water-drill is desirable in any year, if root crops which have to be put in at the driest and hottest seasons are to be successfully cultivated. The same quantity of manure is used as in the dry state, and the quantity of water is regulated by the condition of the land and the dryness of the atmosphere. Superphosphate and guano are the most suitable manures for the water-drill."* Soot is also well adapted for applying in the liquid form, either by means of the water-drill or by flowing on through pipes or otherwise.

* "Soil of the Farm."

CHAPTER X.

WARPING OR SILTING.

THIS species of irrigation consists in repeatedly flooding low-lying tidal or river lands, and allowing a succession of sediment to be deposited. Sometimes the object is only to fertilize the land, but more generally it is practised with the double purpose of raising the surface of low and swampy ground.

In either case, warping depends for its effect upon the presence of much suspended alluvial matter in the water used. Being stirred, and kept in motion by the tide, that alluvial matter is, by the process of warping, conveyed over the adjoining lands and there deposited during a period of rest. As soon as this has been done, the clear water is drawn off slowly, so that the new deposit is not disturbed. Another flood is then admitted, and so on until the warp is completed. In this way the thinnest and poorest soils, if favourably situated, may be covered with the richest alluvial to almost any depth.

One tide will leave, on an average, one-eighth of an inch of warp; and in this way 3½ feet of added soil has been obtained in three or four years. Dr. Anderson tells us that in one experiment, where the water used contained 233 grains of mud per gallon, 210 were deposited during the warping.

Warping is effected by a cut or canal from the sea or river, with sluices for the admission and discharge of the water, which is confined to the grounds intended to be warped by surrounding banks raised to the required height. The higher the banks and the deeper the sheet of water that can be impounded the better, as a greater burden of sediment will be deposited; but the height of the bank is, of course, limited by the difference in level between the land surface and the water in the canal.

In these banks there are fewer or more openings to let in and out the water, according to the size of the field to be warped. In general they have only two sluices, one called the flood-gate, to admit, the other called the waste-gate, to let off the water gently. These are enough for 10 or 15 acres. The flood-gates are placed so high as only to let in spring-tides, and the waste-gates are so constructed as to let the water run off between the ebb of one tide and the flow of the next. To avoid the danger of the newly-deposited matter being stirred up and carried off again by the retreating water, the waste-gates may be made to open at the top instead of at the bottom.

Seasons for Warping.—The dry months of summer are considered the best for this work. Land may be warped, however, in any season, provided the water is always muddy; in other cases it should be practised more particularly when the weather is dry and the fresh water in the river very low. When the season is wet, and the river full of fresh water, warping cannot be advantageously executed. The fresh water then mixes with the tide, makes it not half so muddy and thick, and consequently incapable of depositing the same quantity of sediment.

Effects of Warping.—"It is easy to understand the importance of the effects produced by adding to any soil large quantities of fertilizing mud. Herepath has calculated that, in one particular instance, the quantity of phosphoric acid brought by warping upon an acre of land exceeded seven tons. As, moreover, the matters are all in a high state of division, they must exist in a condition peculiarly favourable to the plant. The overflow of the Nile is only an instance of warping on the large scale, with this difference, that it is repeated once only in every year, whereas in this country the operation is repeated at every tide until a deposit of the desired thickness is obtained, after which it is stopped, and the soil brought under ordinary cultivation."*

The fertility of warped lands is so great that they have been known to yield full crops for fifteen or even twenty years in succession without manure. When laid down in grass seed the land is not warped, for the mud would destroy such a crop.

There can be no doubt, however, that the warp of some rivers is much more valuable than that of others. The value must depend on a variety of circumstances, such as the quantity of valuable ingredients contained in the mud, and the proportion of the several ingredients. The presence of any one useful or essential ingredient must add value to the warp, and the greater the proportion of all of them the more valuable will be the deposit.

Mr. Moncrieff † gives an example of this work having been carried on with great success near Avignon, by means of the water of the Crillon canal. M. Thomas, a merchant of that city, having a property composed of

* Anderson's "Agricultural Chemistry."
† "Irrigation in Southern Europe."

gravel and stones, and fit only for grass crops, laid some of it out in terraces, and obtained the use of 14 cubic feet per second of water from the Crillon canal, which he turned over it for the four winter months of every year. After three years he found he had covered an area of 22·2 acres with a coating of the finest alluvial matter, from 20 to 27 inches thick. The cost of the operation, including a water-rent of 16s., was just £7 per acre. The land, which before had been worth £19 8s. 6d. per acre, was valued after this improvement at £113 7s., and yielded seven or eight crops of wheat without requiring any further manure.

Soils and Situations for Warping.—No land but such as is on a level or below that of spring-tide, or similarly placed for river or canal flooding, can be improved by this process. Of lands so situated there are, however, extensive areas along the shores of the British Empire. In almost every Firth in the three kingdoms, and all along our shores, may be seen extensive tracts of barren sands and mosses which are overflown by spring-tides; and however barren they are, they may be reclaimed and rendered fertile by warping. Cherrycob Sands were reclaimed by this means, and are said to be 4 yards thick of warp.

"Some of the marine mosses are so loose and pulpy in the subsoil that if drained they would be reduced to a level sufficiently low for warping, especially if the coarse and useless herbage on the surface were in the first instance pared and burned. If afterwards warped in the manner above described, they would become the most fertile soils in the empire. Besides, it is often more easy to rebank this than any other soil; for if a river or broad ridge, 30 or 40 feet wide along the bank of the river, were left undug and planted with willows,

it would serve as an impervious bank to shut out or let in the water at pleasure. While the rest of the surface was dug, and drained, and cropped, and thereby reduced to a low level, this bank, left undug, would not sink in the same proportion, but might serve the purpose at least of an excellent foundation for a more solid bank, even though of itself it might be too light, loose, or low to serve that purpose."*

Cost.—The expense of warping has been variously stated at from 30s. to £10 an acre. In ordinary circumstances it can seldom cost more than the smaller sum, as after the banks and sluices are fixed, which outlay cannot be wholly charged on the warping, the only expense will be the occasional wages of a man to attend the sluices. On the other hand, poor land has been so raised in value by this outlay as in many cases to repay the cost in a single year.

* "General Report of Scotland."

CHAPTER XI.

COST OF IRRIGATING LAND.

THE cost per acre of irrigating land will, of course, depend on a variety of circumstances. It will vary according to the mode of irrigation adopted, the nature of the work, the configuration of the land, and the natural roughness or smoothness of the surface, the distance from the source of water-supply, and the means by which the required amount of water can be obtained.

Bed-work irrigation is the most expensive; but even here the cost will vary considerably. If the ground is smooth on its surface, or in regular ridges; if the water can be easily brought to the meadow, and neither wear nor conductor is necessary, the cost may not exceed £3 per acre. If, however, the land has a rough and irregular surface; if a long conductor, and a proper wear be required, with hatches both in it and in the feeders, the cost may be £10 per acre.

"Few people unacquainted with the art of irrigation," says Mr. Stephens, "and the regularity of form which the adjustment of water requires, have any idea of the expense of modelling the surface of a field. Where the ground is nearly level, and the surface covered with turf, the turf may be taken up, the ground properly shaped, and the turf replaced for £3

per acre; as was instanced in one case belonging to the late Sir Charles Menteath, of Closeburn, in 1826; whereas, in a case of Mr. Lawson, of Cairnmuir, in Peeblesshire, the cost was £12 per acre. In one field it cost Mr. Simpson, of Glenythan, Aberdeenshire, about £7, and in another field only £1 16s. 9d. per acre. From £7 to £9 may be taken as a fair average of the expense of converting land into water-meadow. Unless, therefore, the advantage to be derived were considerable, such an expense would not be justifiable; but in all cases where meadows have been well managed the yield has at least doubled."

The expense of forming some of the Wiltshire water-meadows has much exceeded £10 or £12 per acre. £20 and even £40 per acre, have, it is said, been expended in the formation of some of these meadows; but the latter sum seems altogether unreasonable, even for the most elaborate work; though no doubt the value of these meadows, which are worth an annual rent of from £5 to £10 per acre, will warrant a large expenditure, so long as it is judiciously made.

Where a new meadow is to be formed on the bed-work plan, and the ground is favourable, the whole of the work within the boundary fence may be done by the plough, except a little final touching-up and shaping out of the channels and gutters, which would have to be done by the spade, and need not cost more than £2 to £2 10s. per acre. The width of the beds or ridges is first set out, then the land is ploughed two or three times, always "gathering" and "splitting" in the same place, to get the necessary rise and round of the beds. After this the ground is well rolled, harrowed, seeded, and rolled again. It then remains to draw out the feeders on the crowns of the ridges, and

the furrows in the bottoms between the beds. This is readily done by a single turn of the ridging plough. A man follows with a spade and gives the final touch up, and the work is complete. The expense of outside conductors, dams, and wears will not usually exceed a few shillings per acre.

Catch-work irrigation can be practised at very little expense. The cost of forming the furrows by the plough will not often exceed 5s. per acre, and very little spadework is needed. This is decisive in favour of catch-work, where it can be adopted. It also requires much less water, and is often fully as effective as bed-work irrigation. The furrows need to be but very small, as all that is required of them is to arrest the flow of the water, and cause it to spread out equally again in a thin sheet over the whole surface. The total cost of this system, including the expense of bringing the water to the field, need seldom be more than 10s. per acre.

In the foregoing cases nothing is supposed to be paid for the water itself; but in many countries the water rates are high for irrigating land; and it may also occur that there is considerable expense in raising the water and in bringing it to the land after the right to use it is obtained.

In France, where one cubic foot of water per second is used to irrigate 70 acres of land, as much as £100 is paid per cubic foot per second during the season; and the cost per acre varies from £1 5s. to £1 10s. annually.

"In Spain, the Iberian Irrigation Company makes a charge of about 30s. per acre, for twelve waterings per year, equivalent to a total depth of 33 inches of water over the entire surface irrigated.

"In Italy, the average cost of the water to the farmer is from £150 to £170 per cubic foot per second, equivalent to 11s. 6d. per acre for maize, 31s. 6d. an acre for meadows, and £4 an acre for rice."*

The same writer states that in California, Colorado, and other parts of the United States, the "actual cost" of irrigating land "has been found to range from so small a sum as $1 † per acre upwards. That is, a community of farmers, numbering some hundreds, may construct the necessary dams, canals, sluices, and feed-gates, to irrigate 10,000 to 50,000 acres of land at a total cost not to exceed $5 per acre, where the conditions of water-supply, character of soil, and surface of the land are favourable. . . . . This estimate will allow of substantially constructed works, which will require but little repair or renewal to keep them in permanently good condition. Large tracts of land have been supplied with water for irrigation at a much less cost than this, in some cases even so low as 25 to 50 cents per acre; but this cost covers only the construction of the main supply ditch, and not the interior ditches, which, to be permanent, should be well laid out and properly constructed. It is now sufficiently well known, however, that a supply of water for irrigation can be brought to and spread over a farm upon our dry plains at a total expenditure of capital per acre not any greater than the annual rent paid per acre for irrigating water in European countries."

Where the water used in irrigation has to be raised from wells by pumping, or other means, the working expenses will be much increased. In Behar, where well irrigation is common, and the water is usually

* Stewart, "Irrigation for the Farm, Garden, and Orchard."

† The American dollar is 100 cents; equivalent to 4s. 2d.

raised by bullocks working a rope and buckets, one pair of bullocks can, in hot weather, irrigate one-tenth of a beegah per day, and in cold weather one-seventh of a beegah (a beegah is about two-thirds of an English acre). This—allowing four annas* per diem, a low rate of hire, for two labourers; pair of bullocks, wear and tear of rope and buckets, &c.—would leave each irrigation to cost, in the hot weather, Rs. 2 8 0† per beegah, and in the cold weather Rs. 1 12 0 per beegah, *i.e.* from 6s. 10d. to 4s. 4d. per acre.

The crops are usually irrigated four or five times, so that, allowing each watering to cost only Rs. 1 8 0 per beegah, there is still, at lowest calculation, Rs. 6 0 0 per beegah, or about 17s. per acre, expended annually in the mere application of the water.

Canal irrigation costs very much less than well irrigation, where, in the latter case, the water has to be raised by artificial means.

* 1 anna = 1·4d. † 1 rupee = 22·4d.

CHAPTER XII.

SOURCES OF WATER-SUPPLY.

RAIN may be termed the direct source of water-supply, though rain itself is due to the evaporation which goes on from sea and land. The moisture which rises through the air is, in fact, equal to that which falls through it. Every drop of fresh water on the surface of the globe, or within the earth's crust, has been distilled from the atmosphere.

Rainfall.—For drainage works we require to know the maximum fall of rain during storms, but for water supply we must estimate the least quantity of fall.

The comparative quantity of rainfall depends upon the vicinity of mountain ranges, and not upon altitude. The greatest fall occurs in the west of hilly districts. In Great Britain it varies from 15 inches annually, in dry districts in dry years, to 150 inches in wet districts in wet years. In exceptional cases, near the Lake district, as much as 220 inches has fallen in one year. The mean annual rainfall in England is estimated at 32 inches.

Influence of Vegetation on Rainfall.—The fall of rain in any district increases with the increase of vegetation, and especially of forest growth. "Trees and forests," remarks Steinmetz, "contribute to the formation of springs and watercourses, not only by means of the

humidity which they produce and the condensation of vapours by refrigeration, but also by reason of the obstacles which they present to the evaporation of the water in the soil itself, and by means of the roots which, by dividing the soil like so many perforations, render it more permeable and facilitate filtration. The clearing of forests, and the consequent drying up or draining of marshes and bogs, have caused a material alteration, not only in the entire face of the country, but in the supply of water to the rivers formerly derived from those reservoirs, and in the periodical amount of rainfall and the regularity of its distribution." In Germany it is considered that, in order to insure a regular and sufficient rainfall in agricultural districts, the proportion of forest or woodland should not be less than 20 per cent.

Springs.—One of the duties of rain-water is to replenish the deep-seated springs. This is done by that portion of the rainfall which escapes evaporation and drainage, and penetrates into the porous strata of the earth. And that it is the rainfall which is the immediate and only source of supply to all the subterranean reservoirs, as well as to all the surface streams and lakes, it would be easy to prove. It may be daily observed that springs increase or decrease in proportion as it does or does not rain; and if a drought occurs, of a few weeks' duration even, many of them go dry altogether. If the drought were protracted for a year or less, there would be scarcely any springs met with in all the land. The absence of rainfall has the very same effect in diminishing the water of lakes, and it tells far sooner in the flow of rivers.

Water-bearing Strata.—Although a considerable portion of the rain-water, perhaps one-fourth of the

entire quantity which falls on the surface of the earth, penetrates its porous strata, and is gathered in subterranean recesses, there is no more a general distribution of water in the stratification below the crust of the earth than there is on the surface. Yet many thousands of pounds are annually wasted in fruitless attempts to get water where it does not exist.

Predictions of water being obtainable from subterranean sources at a given point on the surface can never be certain without a very thorough knowledge of the geological position, thickness, porosity, dip, and soundness of the strata over all the area that can have influence upon the flow of the percolating water. There are, of course, water-bearing strata; but though plenty of water may be got by sinking at one point, it may happen that only a few rods distant no water will be obtainable in the same stratum, an intervening *fault* having intercepted the flow and led it off in another direction. In one case, after trying a number of places for water, none was found within 120 feet of the surface, and yet close by water was obtained at 40 feet in depth. Sometimes, by the extension of a heading from a shaft in a water-bearing stratum, to increase an existing supply, a fault is pierced, and the existing supply led off into a new channel.

"The underground flow of water towards wells or springs is limited and controlled, not only by the porosity of the strata which it enters, but also by their inclination, curvature, and continuous extent, and by the imperviousness of the underlying stratum. The chalk and limestone do not admit of free percolation, and are unreliable as conveyors of water from distant gathering surfaces, since their numerous fissures

through which the water takes its course are neither continuous nor uniform in direction.

"The mere distance from hills or mountains need not discourage us from sinking wells. Waters are sometimes gathered through inclined strata from very distant water-sheds, and sometimes their course leads under considerable hills of more recent deposit than the stratum in which the water is flowing." *

Commencing with the chalk formation downwards, Professor E. Hull has arranged twelve sets of strata according to their water-bearing quality. Of the twelve seven are permeable, or water-bearing formations, viz.:—(1) Chalk and Upper Greensand; (3) Lower Greensand; (4) Purbeck and Portland beds; (6) Coral Rag and Grit; (8) Oolite and Upper Lias sands; (10) Middle Lias; (12) New Red Sandstone, with a total thickness varying from 1,275 to 5,500 feet; while alternating with the above are five impermeable or dry formations, viz.:—(2) Gault clay; (5) Kimmeridge clay; (7) Oxford clay; (9) Upper Lias clay; (11) Lower Lias and Keuper marls, with a total thickness varying from 2,110 to 5,430 feet vertical.

The water-bearing strata, it is seen, consist of sandstones and limestones of various kinds; the dry formations of clays and shales. Yet the very same "strata that now throw out springs or yield water when pierced would, if occurring at a different level, or if inclined at a suitable angle, become the means of draining water away from other parts than that in which their waters are now collected. This follows as a matter of course, for the conditions would merely be reversed, and the water would pass through the beds

* Fanning, "On Water Supply."

in another direction, the springs of one locality being in fact but the natural drainage of another."

Effect of Drainage on Water-Supply and Floods.—Every inch of rainfall lost by drainage from every acre of ground represents a loss of 100 tons of water to that acre. The average loss of water by drainage throughout the country is probably half the rainfall, but taking it at 10 inches, then the loss will be 1,000 tons per acre, or 640,000 tons per square mile.

The modern system of drainage clears the land of its surplus water almost as soon as it falls, there being now few of the ancient surface reservoirs, in the shape of bogs and marshes, to receive and retain it for future use. It does not follow, however, that the subterranean reservoirs must suffer, because where there is a porous surface stratum (and it is the porous strata only that feed these underground reservoirs) the rain-water falling upon it will sink as before, until the level of supersaturation rises to the level of the drain-pipe, which will only carry off the surplus water.

The immediate effect of the drainage of higher lands has, however, often been to inundate the lower levels, by causing the watercourses of the district to rise more speedily and to greater height than before. But as the flow of the stream is more rapid, and the total volume of discharge is not augmented, the floods subside sooner.

Artificial Sources of Supply.—The foregoing considerations lead to the conclusion that, in all cases of artificial water-supply, it must be obtained from one of two sources—either from subterranean reservoirs, or from surface drainage—and that geological conditions will determine which of these sources can be made most available. Where water-bearing strata can be tapped,

the supply may be obtained by sinking wells; but where the subjacent water-bearing strata lie so deep that the expense of a well would be too great, the supply must be obtained by artificial storage of rain-water and surface-drainage. These different means of obtaining water will be found treated of at length in the succeeding chapters.

The distillation of sea-water is said to be the only means of domestic water-supply in some districts of South America. For agricultural and farm purposes generally, even on the smallest scale, however, the distillation of water would be very far from economical.

Still there are times and places when men cannot afford to disregard any possible means of obtaining even a few drops of water. An Australian recently supplied himself with water in a very novel way, and saved his life by it, while crossing one of the waterless regions of that vast continent. This he did by thrusting the ends of green scrub-wood—"mallee scrub"—into the fire, and catching the sap driven out at the other end in a bark trough. He states that a dozen mallee sticks, 4 feet long and 2 or 3 inches in diameter, would give a pint of water in an hour; and suggests that the same device may possibly be found of vital importance to other bush-rangers and travellers in arid regions.

CHAPTER XIII.

WELLS AND WELL-SINKING.

WELLS are of three kinds:—1. Open Wells. 2. Bored Tube Wells, commonly called "Artesian Wells." 3. Driven Tube Wells, sometimes termed "Abyssinian Tube Wells." One or all of them may be *flowing* wells, or they may not. In the latter case, the water may rise to the surface or near it; but will generally have to be raised some distance by pumping.

Driven Wells, or "Abyssinian Tube Wells."—The newest system of obtaining water from subterranean cavities is by driving a tube into the ground until its perforated end reaches a stratum containing water. When that occurs, the water will immediately flow through the perforations into the pipe; and, if a pump is attached to the upper end of the tube, by pumping for a time, all the particles of sand and fine gravel will be drawn out, and the cavity thus formed around the perforations will remain filled with pure water, as shown in Fig. 23.

Mr. Robert Sutcliff* has given a good account of the process of driving a tube-well:—"In the first place," he says, "the materials used must be of the very best quality, and especially tough and good iron is required for the tubes. The first tube is pointed

* Annual Conference on National Water Supply, 1879.

and perforated up for a few inches, with holes varying from one-eighth to quarter inch. The point is somewhat bulbous; but only sufficiently so to make clearance for the sockets, by which the tubes are connected together. On the tube a clamp is fastened, provided with steel teeth, so as to grip the tube. This clamp is tightened by means of two bolts. Next, a cast-iron driving-weight, or monkey, is slipped on to the tube, above the clamp. The tube, thus furnished, is stood up perfectly vertical, in the centre of the tripod; ropes are made fast to the monkey, and driving is commenced by two men pulling the ropes, and allowing the monkey to fall on the clamp. It is particularly important that the bolts of the clamp are kept tight, so that no slipping takes place. When the pointed tube has so far penetrated the earth that the clamp reaches the ground, the bolts are slackened, and the clamp raised again some two or three feet. Length after length of the tube is thus driven into the earth, being connected together by socket-joints. It will be noticed that the tube well proper is, therefore, self-boring, and that no core of earth is removed.

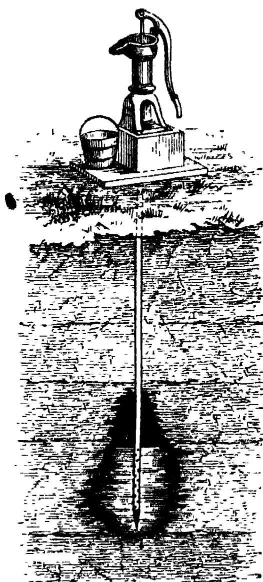


Fig. 23.

"One of the first questions that will suggest itself to a thinking mind is, will not the small perforations

be entirely blocked up by being thus forcibly driven through the earth? This was the American's first idea, and he provided a sort of sleeve, in the shape of a sliding-tube, over the perforations, to protect them from the earth. Experience, however, has proved this protection to be quite unnecessary. The perforations are made about four times as numerous as is necessary for obtaining a full flow of water from the tubes. Earth does find its way into the tube wells in pellets, like the casts from a worm; but some of the perforations are always left sufficiently open to allow water to pass into the well; and, if the soil comes rapidly into the tubes, it is easily mixed with water poured down from the surface, and drawn up by ½-inch tubes, to which a pump is attached.

In the Abyssinian and other campaigns, "the wells were only used singly, as one or two were found sufficient to supply the wants of a number of troops. When, however, large supplies for manufactories, towns, and villages were needed, a fresh development in the system took place. Instead of single wells of great diameter, groups of moderate size were driven, and coupled together by horizontal mains; so that powerful steam-pumps could draw from many wells at the same time. The great friction that would be caused by drawing an enormous body of water to a single spot is thus avoided. Wells so coupled draw from a very large area of ground, and the water-level at any one spot is not so readily lowered. The very action of the pump, too, in drawing the water to the wells, opens and maintains channels of communication which help to keep up the level of the water. In putting down plant for a large supply of water, a trench, hundreds of feet in length, and some two or three feet in depth,

is dug; and tubes are driven every 20 feet, and coupled by mains as already described.

"It may be interesting to refer to some particular instances, where large supplies of water are thus obtained. At West Thurrock, in Essex, a cement company is pumping from two 5-inch tube wells, about 80 feet deep, 220,000 gallons per day of 10 hours. Another cement works at Northfleet is pumping 60,000 gallons per day. These have been pumped daily for about four years, and still give a constant supply. As expense is an important feature, it may be mentioned that the cost of these did not exceed £60 each. The coupled tube wells are to be found in greatest numbers at the centres of beer manufacture, where abundance of pure and cool water is an absolute necessity. At Burton-on-Trent about two million gallons are pumped daily from these wells.

"When rock, solid stone, or incompressible clay is met with, a tube cannot be driven through it without first making a hole and removing the cores. In some cases, however, there may be many feet of loose earth which can be easily driven through. The tubes, therefore, may be fitted with a temporary hard wooden point, which will allow them to be driven through the soft earth, and when an obstruction that cannot be penetrated is met the point is knocked out, and, being wood and in sections, it floats to the surface of the water and leaves an open-ended tube, through which ordinary boring tools can be passed to chisel and break up the rock. A tube can frequently be driven through gravel and clay to a depth of, say, 70 feet in a single day. To bore to the same depth in a similar stratum frequently takes ten days or a fortnight. The saving that may be effected by driving through the loose stratum can,

therefore, be readily appreciated, and what is still more important, the upper part of the tubes are fixed more tightly in the ground than if a boring had been made to receive them. In some cases, however, hard strata come right to the surface, and the boring operations, consequently, cannot be deferred. When this is the case, instead of using a pointed tube, an open-ended steel-shod pipe is driven into the hole as the boring proceeds. As the tools pass down inside the pipe they do not cut so large a hole as the outside circumference, and some little trimming down of the sides is left for the steel shoe to perform.

"In great depths the single tier of pipes with which the work is commenced cannot be forced the whole way. Tubes, therefore, of smaller diameter are inserted; but, as to pump by the tube-well method air-tight joints are absolutely necessary, the final tube is continuous from the deep spring to the surface. In this way tube wells 300 and 400 feet in length are put down, and if the spring, when tapped, rises to the surface, or within, say, 25 feet of it, only an ordinary lift pump is required to obtain the supply. Where the water does not rise to the required height, a deep-well pump can be lowered into the tube well, and worked by rods from the surface."

The latest method of driving tube wells is more particularly applicable to tubes of large size, and is so simple as to merit a brief notice. "An elongated cylindrical weight passes down inside the tube, and the blow, instead of being struck at the surface, is delivered where it is wanted, near the point which penetrates the earth. As water in the tube would impede the force of the blow, the first socket above the perforations is made sufficiently long to admit of a stout iron ring or washer

being placed in the centre of it in such a way that the two lengths of tube, when screwed tightly together, butt against it, one on the under, and the other on the upper surface. The interior of this ring is of sufficient size to allow the water to pass freely through it, but it has a screw thread cut throughout its whole length. During the operation of driving, the opening in this ring is closed by a steel plug, which is screwed down into it until its shoulder butts on the ring. The upper surface of the plug forms an anvil, on which the driving weight falls. The plug is readily removed and brought to the surface when the required depth has been reached."

"Artesian," or Bored Tube Wells.—Where driven tube wells are not practicable, from the nature of the strata which have to be passed through, artesian wells may be attempted. These are simply open-ended steel-shod pipes, which are driven down after the drill as it bores through the rock, the core of earth at the same time being brought to the surface.

The term "artesian" is only properly applied to wells in which the water rises to or above the surface. But many so-called artesian wells are not "flowing" wells, the water supplied by them having to be raised partly by pumping.

Self-flowing wells and springs are similar in action, and their principle is this: water percolating through pervious strata, such as sand, gravel, or chalk, is finally arrested in its downward course by an impervious stratum of rock or clay, causing it to accumulate in the pervious strata above as in a reservoir, and when the source of supply is higher than the ground at the place where the well is bored, the water will rise to the surface, or even considerably above it.

The process of sinking artesian wells of great depth

is attended with considerable difficulty and expense, but in many cases it is not necessary to go very deep. There are cases on record where a couple of men have completed a flowing artesian well in a few hours, and the tools used were carried on their backs. For larger operations a steam driller may be necessary, but smaller sets of the same machinery are made for working by horse, and even by hand power.

Some soils are easier operated in than others, but when the depth is not very great, if no rocks or boulders are met with, there will be no difficulty about the sinking.

In some formations—such as granite, hornblende, and limestone—artesian wells are not generally successful, unless water is reached before touching the solid rock. Where rock has to be passed, the expense is more and water uncertain, unless the geological conditions of the district are well understood.

"Among the causes of the failure of artesian wells," says Mr. Spon, "we may mention those numerous rents and faults which abound in some rocks, and the deep ravines and valleys by which many countries are traversed; for when these natural lines of drainage exist, there remains a small quantity only of water to escape by artificial issues. We are also liable to be baffled by the great thickness either of porous or impervious strata, or by the dip of the beds, which may carry off the waters from adjoining high lands to some trough in an opposite direction—as when the borings are made at the foot of an escarpment where the strata incline inwards, or in a direction opposite to the face of the cliffs."

The artesian well at Passy, for supplying water to Paris, is probably the largest well of the kind yet attempted. It is carried through the chalk into the

lower greensands, which were reached at a depth of about 1,900 feet, the bore finishing with a diameter of 2 feet. The first water-bearing strata was reached at a depth of 1,894 feet, but the water did not rise to the surface. At length a true artesian spring was tapped at a depth of 1,923 feet, yielding 5,582,000 gallons per day. The total cost of the well was £40,000. It was laid with solid masonry to a depth of 150 feet, then wood and iron tubing was introduced to 1,804 feet from the surface, and below that there was a length of copper pipe pierced with holes.

There are, however, many deeper wells than that at Passy. The artesian well at Belcher's sugar factory, St. Louis, is 2,197 feet deep. It was finished in thirty-three months, at a cost of 10,000 dols. If report is true, the same American city can probably claim to have the deepest well in the world, for another artesian boring at St. Louis is said to have reached a depth of 3,850 feet, or 3,000 feet below the level of the sea.

Along the lines of the great railroads which now traverse the American continent, from the Atlantic to the Pacific, water is obtained at certain points by means of deep artesian wells for supplying the necessities of the roads. This, though often the only resource in the uninhabited and waterless districts passed through, is not successful at all places, and at hundreds of railway stations on these lines every drop of water they get, even for drinking and culinary purposes, has to be brought long distances by rail on special water-trains, which it is incumbent to run once or twice a day for that purpose.

During the autumn of last year we spent several weeks on the Texas Pacific and the Southern Pacific Railroads, and the lands immediately adjoining them; and, west of

the Pecos river, at least, at all the stations along these routes, took notes of what had been done, or was being done, in order to obtain a sufficient water-supply. Thus, at Wild Horse Station, on the Texas and Pacific road, we found two wells had been bored, and plenty of water obtained in both, at a depth of 350 feet. Ten miles farther on, at Van Horn Station, a depth of 750 feet was reached before obtaining water. None of these wells, however, are self-flowing, and pumping-engines of about 35 horse-power, with two men in attendance, were employed at each of them for raising the water.

At Haskell Station, on the Southern Pacific road, and only eight or nine miles south of Van Horn, a boring had been made to the depth of 1,200 feet without finding water. At Sierra Blanca, forty miles farther west, where the two roads unite, water had not been found at a depth of 700 feet. At Finlay Station, twenty-one miles west of Sierra Blanca, the boring had been stopped at 200 feet without any signs of water.

A similar record could be given as the result of borings at more than a dozen other stations on the railways skirting the upper valley of the Rio Grande.

At the time of our visit, the prices being paid for boring were at the rate of $3 per foot for the first 100 feet, increasing half a dollar per foot every 50 feet beyond that depth. The bores were generally 7½ inches in diameter.

Ft.		Ft.	dols.	cts.		Ft.		Ft.	dols.	cts.	
1	to	100 =	3	00	per foot.	550	to	600 =	8	00	per foot.
100	,,	150 =	3	50	,,	600	,,	650 =	8	50	,,
150	,,	200 =	4	00	,,	650	,,	700 =	9	00	,,
200	,,	250 =	4	50	,,	700	,,	750 =	9	50	,,
250	,,	300 =	5	00	,,	750	,,	800 =	10	00	,,
300	,,	350 =	5	50	,,	800	,,	850 =	10	50	,,
350	,,	400 =	6	00	,,	850	,,	900 =	11	00	,,
400	,,	450 =	6	50	,,	900	,,	950 =	11	50	,,
450	,,	500 =	7	00	,,	950	,,	1000 =	12	00	,,
500	,,	550 =	7	50	,,						

At the above rates the cost of a well 1,000 feet would be $7,255. These prices, however, only included labour, the railway companies finding tubes, tools, engines, and fuel, &c.; so that the total cost must have been considerably greater. An engineer in charge of the boring at one of the stations told us that, making allowance for accidents, the actual total cost of one of these wells would be nearly double the above sum.

At Chicago, where there are upwards of twenty artesian wells, varying in depth from 1,200 to 1,640 feet, the average cost was found to be $6,000 for a 5½-inch bore, and $5,000 for a 4½-inch bore, in each case 1,200 feet deep.

No doubt, where the bore is less than 100 feet in depth, it can be done at a small outlay. We have heard a practical man say that, in easy working soil, it would then be profitable at $1 a foot; and that the tools and entire outfit for sinking such a well need not cost more than $75. The tubes would cost about 15 cents a foot.

As to the cost of boring artesian wells in England, we will quote Mr. Spon: "Boring," he says, "is usually executed by contract. The approximate average cost in England may be taken at 1s. 3d. a foot for the first 30 feet and 2s. 6d. a foot for the second 30 feet, and continue in arithmetical progression, advancing 1s. 3d. a foot for every additional 30 feet in depth. This does not include the cost of tubing, conveyance of plant and tools, professional superintendence, or working in rock of unusual hardness, such as hard limestone and whinstone."

Open Wells.—All the old domestic wells are of this class, and have been formed by digging or sinking a shaft of several feet in diameter. Owing to the great

expense of doing this they are naturally of very limited depth as compared with the tube wells we have previously been discussing, few of them exceeding 60 feet, and the majority of them probably not reaching half that depth.

Very few open wells are now dug. Besides the question of greater expense, there are many objections to them, which the deeper tube wells are free from. In many cases the open wells are merely catch-water tanks, and even where water does rise in them from below, it is liable to be spoilt by the drainage from the surface carrying organic matters into the well.

In sinking a well of this kind the top waters, to a depth of 10 or 12 feet, should be carefully stopped off by solid masonry or hydraulic cement, and means adopted for keeping it free from contamination.

The water is raised in many open wells by pumping, but the old plan, which is still extensively in use in rural districts, was to *draw* water from the well by means of a rope and bucket.

The cost of digging a well in a clay soil, and building a well ring, say 3 feet in diameter, will be about £10 for the first 20 feet in depth, the expense increasing considerably in proportion for every foot of additional depth. This is exclusive of winch or pump, &c.

CHAPTER XIV.

CATCH-WATER RESERVOIRS.

In cases not admitting of supply by means of wells, and where springs do not appear on the surface, the fluctuation of the rainfall, and consequently the flow of streams at different seasons of the year, require almost invariably that there shall be artificial storage of winter rainfall for summer use. When the mean annual requirements, whether for domestic use, for hydraulic power, or for live stock and irrigation purposes, one or all combined, are nearly equal to the mean available rainfall, the question of storage becomes of supreme importance.

Determination of available Rainfall.—For measurement of rainfall two kinds of data are required: (1) drainage-area, catchment-basin, or gathering-ground; (2) depth of rainfall.

Drainage areas are usually bounded by water-shed lines. The water-shed does not always, however, prove the drainage boundary; as, for example, when a porous superstratum overlies an impervious stratum. In such cases the drainage boundary will not be at A but at B (Fig. 24). Artificial watercourses and drains may also lead the water away from its natural course ; but while this will diminish the yield of one water-shed, it will add to the natural supply in another place.

Steep rocky surfaces, or clay soils, make the best gathering-grounds, as the rain-water flows rapidly off them and less is lost both by evaporation and absorp-

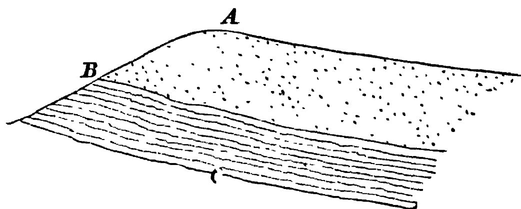


Fig. 24

tion than on flat and porous surfaces. Sand, gravel, and chalk, as well as many of the softer sandstones, are all so exceedingly absorbent that the rain is swallowed up as fast as it falls on them.

We have, then, only this general rule: Water-shed lines are the boundaries of the basins, but geological features may affect the quantity as already described.

The available rainfall of a district is that part of the total fall which remains to be stored or carried away, after deducting the losses by evaporation, percolation, absorption by plants, and other causes. The proportion which this bears to the total rainfall varies very much, being affected by the distribution of the rainfall, the porosity of the soil, the steepness or flatness of the ground, the nature and quantity of vegetation upon it, the temperature and moisture of the air, and other circumstances. Upon average drainage areas, and including floods and flow of springs, it may ordinarily be taken at about 50 per cent. of the annual rainfall. For different surfaces its ratio is more approximately as follows:—

On primary rocks . . .	nearly 1·
On moorland and hill pasture	·8 to ·6
On cultivated land	·5 „ ·2
On chalk ditto	0.

Assuming then that half the rainfall can be made available for storage, a fall of 32 inches per annum leaves us 16 inches, or 16·16 tons per acre.

But there are losses incidental to storage which must not be overlooked. Reservoirs constructed on the surface of the ground are seldom perfectly water-tight, and a certain amount of percolation is almost inevitable. More or less evaporation will also take place from the surface of the reservoir. The amount of evaporation from the surface of water has, in England, been found to be 18 inches or more per annum; but the percentage of storage water lost by evaporation will of course depend on the superficial area of the reservoir, and in any case will be comparatively small. If these two losses, however, taken together, amount to 6 or 7 per cent. of the reservoir water, it takes 1 inch off the available rainfall, and leaves us with only 15 inches available for consumption.

When water is impounded in manufacturing districts, it is common to allow from $\frac{1}{4}$ to $\frac{1}{3}$ of the available supply to the riparian owners, leaving $\frac{3}{4}$ or $\frac{2}{3}$ for the impounders.

Site of Reservoir.—This should be carefully chosen in regard to the gathering-ground, the nature of the surrounding and underlying soil, the requirements of live-stock, irrigation, and agriculture in general, as well as the cost of construction. The most favourable site, as affecting cost, is where a comparatively small embankment, thrown across a gorge or valley, will form a large reservoir with the water retained on three sides by the rising ground. An impermeable clay surface is as important as the configuration of the ground, as it not only influences the cost of puddling, but the proportion of the rainfall which can

be collected, and also its retention in the reservoir is largely dependent on this feature. The position of the reservoir for supplying grazing stock with water, or for irrigation or other purposes, is of less consequence than obtaining a good storage, unless the reservoir is so distant from the place of consumption that the cost of delivery pipes would defeat the object of storage altogether.

Capacity of Reservoirs.—As a matter of economy, it will always be better to construct one large reservoir than two smaller ones to hold the same amount of water; but there is of course a practical limit to the height of the dams. Deep open reservoirs, however, are in all cases preferable to shallow ones, for other reasons besides that of first cost; for where the surface is large in proportion to the capacity of the reservoir, the greater will be the evaporation, and shallow water also encourages the growth and decay of vegetable matter.

Construction of Reservoirs.—Small reservoirs, such as would generally afford sufficient supplies for all agricultural purposes, need entail only a moderate amount of engineering skill and of pecuniary outlay. Where a ravine or gorge can be converted into a storage reservoir, no excavation will be needed, and the only expense will be that of constructing the dam, unless the bottom requires puddling. In such situations, however, the dam must be of great weight and strength as well as height.

The Texas and Pacific Railway Company conceived the idea of obtaining a large water-supply from a reservoir of this kind, near Carisso Pass, where the position was favourable for forming a lake basin of very large area. At a point where the gorge between two mountain ranges narrows to a width of perhaps 60 yards, an

embankment, some 75 feet wide at base, 20 feet at top, and 24 feet high, was thrown across it. Riding over the waterless prairie, some miles to the south of this spot, we noticed the artificial mound, and guessing its purpose, was lured out of our way, partly through interest in the scheme, and partly that we might quench our thirst in the cool and pleasant waters of the imaginary lake which was in hiding on the other side. But not a single drop of water was there! The scheme had been carried out regardless of geological conditions, which, on the gigantic surface of the lake (that ought to have been) there had been no attempt to rectify by art. The floods had been there in their season, as was attested by the water-mark on the inner side of the embankment, and the embankment had stayed the torrent of water which had rapidly arisen behind it; but the basin of the reservoir was sandy and porous, and appearances too plainly showed that the whilom lake had vanished underground, when the floods were over and the dry season set in.

In some places a natural hollow exists, which, with very little excavation, can be made to form a capital reservoir. A reservoir on level ground will entail more labour; but it is not always necessary in this case even that the entire capacity of the reservoir should be excavated; for provided water can be led on from higher ground, a small portion of digging need only be done, and the excavated material used for raising the sides, making about two-thirds of the capacity due to embanking, and only about one-third to excavation. The principle of this reservoir is, however, objectionable, owing to the sides being raised so much above the natural level of the ground; so that, even where it could be filled to that raised level, it

may be better to excavate to the full extent if necessary.

An excavating scoop, which is manufactured by Messrs. John Fowler and Co., will be found to greatly facilitate and cheapen the construction of these reservoirs. The implement in question was originally designed for making large ponds or reservoirs on Australian sheep farms; but its successful employment for this purpose has led to other application of it, and it is now used for other descriptions of excavating work, and particularly for levelling land and constructing dams. The scoop is worked by drawing it backward and forward between two steam-ploughing engines, in the same way as the implements employed in the double-engine system of steam-ploughing tackle, the engines being placed one on each headland, and the implement being pulled backward and forward between them. The scoop is, however, always filled by one of the engines, the other engine being used only for pulling the loaded scoop to the point where it is required to discharge. By ploughing the ground first, and using the scoop after, an extensive basin can soon be scooped out on the levelest surface; the depth being determined by the number of times the operations of ploughing and scooping are repeated.

Where the bottom of the reservoir is of a porous nature, it should be puddled to make it retain water. Where clay is not available for puddle, all that is necessary is to cover the bottom with loam to the depth of 12 or 18 inches, and then puddle or work this well with water till it will allow none to percolate. This working, or puddling, may be done by turning a flock of sheep or a herd of cattle into the bed of the reservoir to trample it well when wet. A similar practice

is followed in India. When it is required to make the bed of a reservoir water-tight, they keep it wet and turn buffaloes into it, as their treading effectually puddles the bottom, and prevents water being lost by percolation.

In the construction of small reservoirs, and certainly of underground tanks, the use of concrete may be advisable. Common lime, properly slaked, and mixed with sand, if faced with cement, will make admirable tanks. Portland cement is a double silicate of lime and alumina, made from the deposits of chalk and alluvial clay on the shores of the rivers Thames and Medway, and possesses the property of setting and hardening under water. One barrel of Portland cement mixed with 16 gallons of water, if laid on half an inch thick, should cover 100 square feet of surface. One barrel of Portland cement and two barrels of clean sharp sand, mixed with 23½ gallons of water, should cover 219 square feet of surface to the same thickness; and one barrel of cement and three barrels of sand, with 28½ gallons of water, should cover 285 square feet of surface. The composition of cement and sand may be used if allowed to set before water is let into the work.

The mode to be employed in filling the reservoir, and the best means of providing for overflow, will be suggested by circumstances.

For drawing off the water from the reservoir, the employment of one or more large syphons will probably be preferable to making an opening in the embankment. On a level surface the water may have to be raised by pump, in order to distribute it by gravitation.

CHAPTER XV.

RAISING WATER BY MECHANICAL MEANS.

In irrigation works of any great extent the question of raising water by artificial means may be dismissed, as too expensive an undertaking for individual enterprise. Where, however, circumstances favour a unified system of irrigation, and the scheme is generally adopted by landowners or occupiers, and carried out as a public work under proper control, it may be otherwise.

In Egypt, for example, where some improvement of the present system is urgently called for, two schemes for improved irrigation by raising water by means of pumping are now under the consideration of the Government. The first of these, presented by the Minister of Public Works, proposes to fill the lesser canals during the dry season. The second proposal, which is favoured by the Public Works Company, is to keep the great summer canals perpetually full and to unify the canal system. The former project would be the less costly, and the amount requisite for it might, perhaps, be met by a slight increase in the land-tax on lands already watered, and a tax on lands expected to be reclaimed. In return, a partial exemption from the *corvée* would compensate the fellaheen from the increased burden. The latter scheme would call for a heavy outlay, but would abolish the

corvée entirely; and, in the event of a deficit, the Government would endeavour to meet it by an extraordinary budget rather than impose a new water-tax. The experiment of artificially raising water by steam-pumping has already been tried in the province of Behera, with very discouraging results; but this is attributed to the bad quality of the machines. Before sanctioning either scheme, the Government will, probably, cause experiments to be made in one or two provinces.

As already remarked, however, where irrigation is a work of individual enterprise, it cannot be practised with profit on an extensive scale, unless the water is delivered by gravitation from an elevated canal, river, or impounding basin. As there are thousands of situations where the only source of water-supply is below the level of the land to be watered, the effect is practically to prohibit the artificial application of water to such lands on a large scale.

It is different in garden culture, and in market-garden farms, where the area of land under cultivation is comparatively small, and the value of the produce is far greater than in ordinary farming. The difficulties in the way of raising a sufficiency of water for irrigating garden crops in dry weather are not so insurmountable; and the expense will, in most cases, be amply repaid by the increased profits.

For other purposes than irrigation—the wants of live-stock, for feeding engines, and driving machinery, and for domestic purposes—though the need of water is greater, it is required in smaller quantities; and the cost of raising it, when the source of supply is below the level of the place where it is to be used, is then a subsidiary consideration.

As regards the most economical power and machines

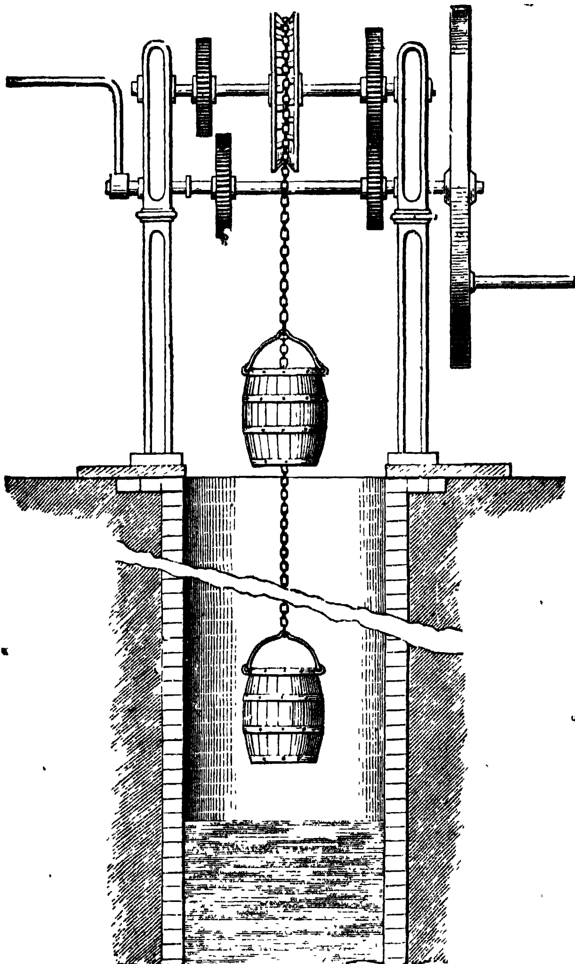


Fig. 25.

for raising water, much will depend on the height of

the lift and the quantity to be raised. Hand or animal power, steam, wind, and water, are all employed as motive-powers for this purpose; and the instruments for utilizing the power so used vary from the primitive rope and bucket to the water-ram and the steam-pump.

For raising water from open wells, the rope and bucket is the most simple means. An improvement on the old mode of drawing by bucket is shown in Fig. 25, as designed and manufactured by S. Owen and

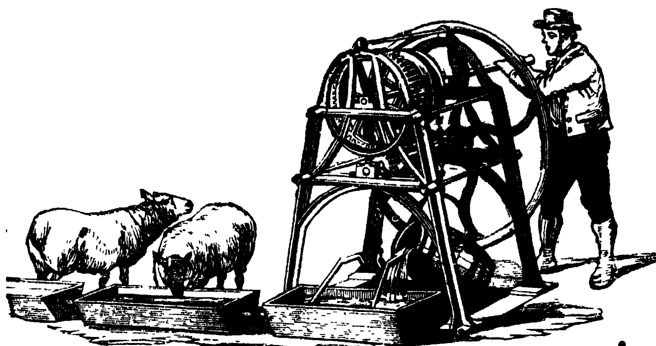


Fig. 26.

Sons, London, in which a windlass is erected over the well, and two buckets are in use, one filling while the other is emptying. Where required, a self-tipping apparatus is provided, with a cast or wrought iron trough, into which the buckets discharge themselves as they reach the surface. In Fig. 26, part of a series of troughs is shown connected together by short pieces of flexible or other pipe, so that any number can be filled for watering a large flock of sheep (as required in the Australian colonies, &c.), the man at the wheel keep-

ing at his work while the self-acting apparatus fills his troughs. This apparatus for raising water is also largely employed for deep wells in many parts of

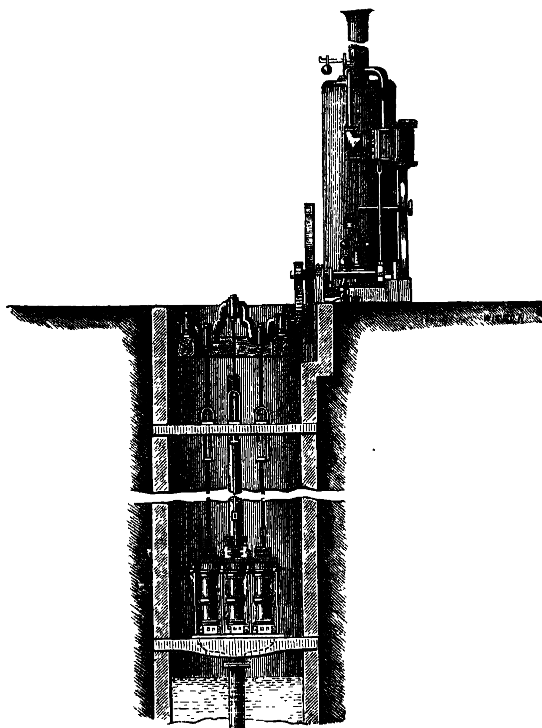


Fig. 27.

England where pumps would be expensive, and the labour required to work them great.

When a large and continuous supply of water has to be raised by this method, a pony or donkey may be employed to hoist the buckets. On the Continent, this

mode is practised successfully, and the pony is trained to work without attendance.

Well Pumps.—The pump, however, is a more convenient instrument for raising water from wells than the rope and bucket. For low lifts, under 26 feet, the common suction, or lift pump, is sufficiently powerful; but for deep wells, force-pumps, or suction and forcing pumps, of the treble or double barrelled type, with valves in the buckets, and an additional retaining-valve for lifts over 100 feet, will have to be used. In these pumps the rods pass down inside the rising main pipes, which are of larger diameter than the working barrels, thus allowing of the buckets and valves being drawn up for repair through the pump-head or cover, which is fixed above the highest level to which the water is likely to rise under any circumstances. Without some such provision, access could not be gained to the working barrels and lower valves should they become immersed, or where they are confined in a small bore hole.

Fig. 27 represents a small steam-engine working a set of Warner & Sons' treble-barrelled deep-well pumps. The same class of pumps can be furnished for water, wind, horse, and even for manual power.

Where only small supplies of water are needed, the question of raising it from deep wells by manual power is, however, so difficult to arrange, that small motors, of one or more horse-power, worked by gas or hot air, are commonly employed, especially in country houses. They are more economical than steam, and do not require skilled labour.

Power required to raise Water from Deep Wells.—Appleby gives the following table of power required to raise water from deep wells by pumping:—

Gallons of water raised per hour ...	200	350	500	650	800	1000
Height of lift for one man, in feet	90	51	36	28	22	18
" " " donkey "	180	102	72	56	45	36
" " " horse "	630	357	252	196	154	126
" " " H.P. steam-engine "	990	561	396	308	242	198

A good high-pressure steam-engine should raise 3,300 gallons 1 foot high per minute per nominal horse-power; the friction of the pump being compensated by the excess of the indicated power over the nominal.* The power required depends, of course, on the height to which the water has to be raised.

Rule for finding required Horse-Power.—For calculating the horse-power required to raise a given quantity of water to a given height, we have this general rule: multiply the weight in pounds of water to be lifted in one minute by the vertical height in feet, and divide by 33,000.

Example.—Find the horse-power that will be required to raise 2,000 gallons of water per minute to a height of 100 feet.

A gallon of water weighs 10 lbs. Therefore

$$2{,}000 \times 10 \times 100 \div 33{,}000 = 60{\cdot}60 \text{ H.-P.}$$

Many engineers add one-fifth for friction. This would bring the required horse-power in the example up to 72·72.

Cost of Pumping.—Mr. Fanning gives the following among other examples of the cost of pumping water in various American cities by steam-power and by water-power:—

* Box, "On Hydraulics."

COST OF PUMPING WATER

PER MILLION GALLONS IN VARIOUS AMERICAN CITIES IN 1875.

City.	Power employed.	Lift in feet.	Millions of gallons pumped during year.	Pounds of coal per million gallons.	Cost of coal per million gallons.	Wages of labour per million gallons	Cost of repairs per million gallons.	Cost of engine-man's stores and supplies per million gallons.	Total cost of pumping one million gallons.	Cost of raising one million gallons 100 feet.	Pounds of coal used to raise one million gallons 100 feet.
					dols.	dols.	dols.	dols.	dols.	dols.	
Brooklyn, N.Y.	Steam power	176·3	9998·00	2703	8·44	3·64	1·45	1·97	15·50	8·79	1533
Jersey City, N.Y.	,, ,,	160	4439·26	—	18·33	—	—	—	18·03	11·27	—
Chicago	,, ,,	120	10957·25	3095	8·91	1·59	·14	·21	10·81	9·00	2571
Indianapolis, Ind.	,, ,,	117	353·29	1697	14·11	16·01	2·31	3·12	35·55	30·38	1450
Montreal	,, ,,	165	1326·47	6204	16·08	7·86	·94	2·30	27·18	16·47	3760
Philadelphia	Water power	90 to 115	7670·1	—	—	1·57	·13	·39	2·09	2·15	—
New Haven	,, ,,	115	1769	—	—	1·00	—	·33	1·33	1·16	—
Manchester	,, ,,	113	424	—	—	2·60	·16	1·30	4·06	3·59	—
Montreal	,, ,,	165	1879·56	—	—	·76	1·33	1·33	3·42	2·07	—

Centrifugal Pumps.—For raising a large volume of water to a moderate height this class of pump is invaluable. The limit to which it can be economically employed depends upon circumstances which are constantly varying. It is used to raise water to a height of 40 or 50 feet at times, but is best adapted to lifts not exceeding 25 feet.

An advantageous arrangement is to work these pumps

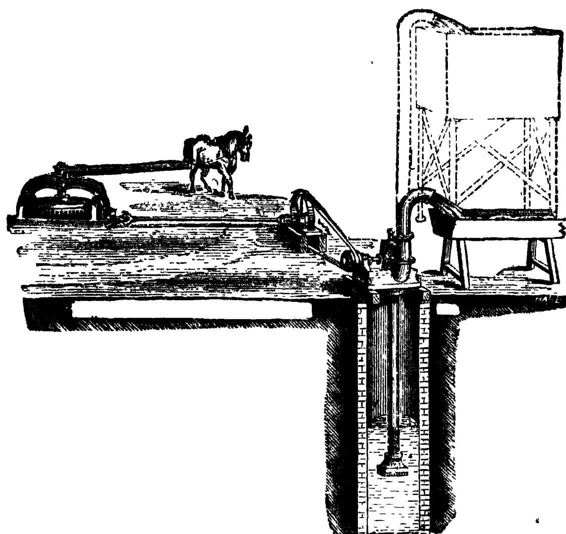


Fig. 28.

by a portable engine, as not only can both the engine and pump be placed in any position most suitable for working, but when not required for raising water the engine can be easily detached, and applied to any work for which portable engines are adapted—such as sawing, threshing, grinding, &c.

On low-lying lands an engine and pump of this class

is invaluable for draining, as well as irrigation purposes. The smaller sizes are adapted for being worked by horse-power or by bullocks. Fig. 28 shows a pump of this kind being worked by a horse. It is manufactured by Messrs. Hornsby & Sons, Limited, Grantham.

The following table gives the nominal horse-power required for the discharge of given quantities of water with lifts of 10 and 20 feet:—

Diameter of pipe.	Gallons discharged per minute.	Nominal H.P. required for a 10-foot lift.	Nominal H.P. required for a 20-foot lift.
Inches.			
3	100	1	2
4	200	1½	3
5	350	2	4
6	500	2½	5
7	750	3	6
8	1,000	4	8
10	1,500	6	10
12	2,300	8	14
14	2,800	10	16
15	3,300	12	20
18	6,000	20	35

Wind-Power.—The objection to windmills in drainage works was, that this power was too variable to be relied upon for keeping the water down to a certain level. There can, however, be no such objection when windmills are employed to raise water from wells for irrigation purposes, or for watering live stock, if storage reservoirs are provided equal to, say, a week's supply. By this means the wind can be utilized whenever it blows, and none of the water is wasted. The windmill works night or day, as called upon by the passing breeze; it wastes no water, requires no fuel, and needs no attendance. There are few field-pumps that might not be

effectively worked by a small windmill, and a larger one will many times furnish a full water-supply for every purpose on the farm. Where water has to be raised for gardens, a windmill is indispensable. On the dry plains of the far West, too, where deep wells have

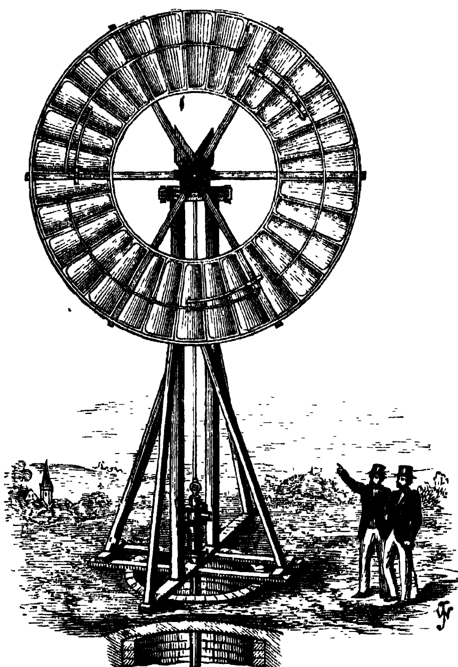


Fig. 29.

been sunk, but are not self-flowing, the windmill is the only means of economically bringing the water to the surface, and of enabling stock-grazing to be carried on with success and profit. The wells may be many miles from the homestead, but a windmill-pump will keep up an unfailing supply of water without the daily attention

of the stockmaster, and at no cost for wages and fuel. Fig. 29 represents a windmill working a well-pump, as erected by J. Warner & Sons, London.

Self-regulating windmills are now made of two kinds. In one kind the circle of fans faces the wind at all times, but their angle to the wind is changed with its force. The other is the "solid wheel," the fans being all fixed, which swings round with its edge against the wind, when it becomes violent, by a self-regulating arrangement, which is partly effected by the centrifugal force of weights, and partly by the direct pressure of the wind. In the former, the self-regulating contrivance is as follows: When the mill begins to run too fast it pumps water rapidly into a chamber or cylinder, and this increase of water moves an arm, which turns the fans edgewise to the wind. When the wind slackens, a reverse movement takes place. By these arrangements the mills are rendered perfectly safe even in a gale of wind. Both these forms are well adapted to farm purposes and pumping water for cattle. They are made of various sizes, and range in price from £10 to £200.

Water-Power.—Water, like wind power, is more economical than steam power for pumping purposes when it can be conveniently employed. Our illustration (Fig. 30) shows an overshot water-wheel, by S. Owen & Sons, London, working a set of treble-barrelled pumps for the supply of a farm, &c., where a large quantity of water is required. In other cases, breast or undershot water-wheels may be employed, and they can be worked with any water that is available. Mr. Wheeler gives an instance of a water-wheel working treble-barrelled pumps, for the supply of pure water for a mansion, homestead, gardens, stables, &c., the motive power being sewage; and in another case, where the

water is taken from the duck pond, to pump pure water from the well. The wheels and pumps cost from £76, for supplying 1,700 gallons a day, through 1,200 feet of inch pipes, with 90 feet lift, the fall for working

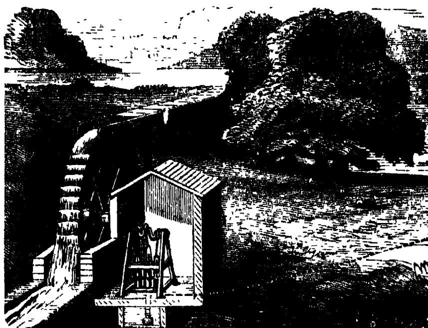


Fig. 30.

the wheel being only 5 feet; to £133 for supplying 1,200 gallons through 1,600 feet of piping, with 165-feet lift. Mr. Clutton states that the cost of fixing water-wheels 8 feet in diameter, in the neighbourhood of the Cotswold Hills, for the supply of farm premises and cottages, was from £55 to £70.

Noria, or Persian Wheel.—Markham* thus describes the use of the Noria (Fig. 31) in Eastern Spain, for raising water to irrigate terraced fields on different levels above the canal: "These norias are of extreme antiquity, having been used in one form or another from time immemorial by Eastern nations. A deep channel is cut from the canal, over which a huge timber wheel is placed, upwards of 15 feet in diameter. By its side are two stone pillars supporting a cross-beam,

* "On Spanish Irrigation."

to the centre of which an upright beam is attached. This upright beam is the axle of a double wheel working horizontally, the two parts being joined by strong battens which lock with cogs in the great wheel. A long pole is fastened to the upper part of the upright beam, to which mules are harnessed and driven round. They move round the horizontal wheel, the battens of which

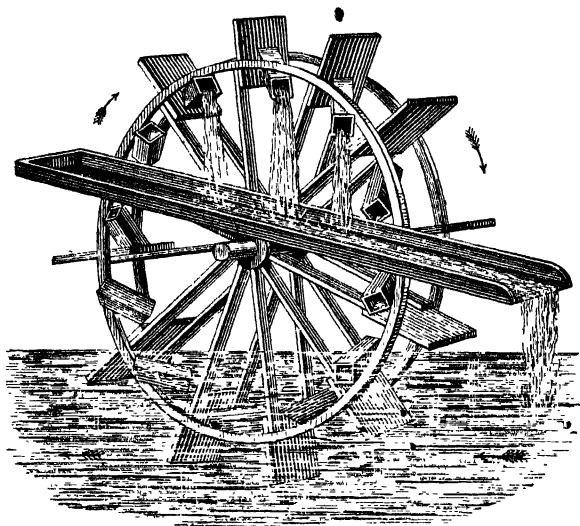


Fig. 31.

lock with the cogs in the great wheel and turn it round. The great wheel is fitted with a succession of boxes round the circumference, which fill when at the lower end of their revolution, bring the water up, and pour it into a trough leading into a channel. Thus the fields up to 15 feet above the level of the mother canal are irrigated. The upper channel brings the surplus

water to another large wheel, which raises it in the same way to terraced fields at an elevation of 30 feet above the mother canal. The norias in Algiers and elsewhere are usually fitted with earthenware jars, instead of boxes round their circumference."

Hydraulic Ram.—The improved self-acting hydraulic ram is a highly useful and efficient apparatus, and is now much employed for raising water for such purposes as irrigating lands and supplying farm buildings. Fig. 32 shows its construction and principle of working. "Its principal parts are the reservoir or air-chamber (*a*), the supply pipe (*b*), and the discharge pipe (*c*). The running stream rushes down the supply pipe (*b*), and striking the waste valve (*d*) closes it. The stream being thus suddenly checked, its momentum opens the valve (*e*) upwards, and drives the water into the reservoir (*a*) until the air within being compressed into a smaller space by its elasticity, bears down upon the water, and again closes the valve (*e*). The water in the supply pipe (*b*) has, by this time, expended its momentum and stopped running; therefore the valve (*d*) drops down again, and permits it to escape. It recommences running, until its force again closes the water valve (*d*), and a second portion of water is driven into the reservoir as before—so it repeatedly continues—the great force of the compressed air in the reservoir driving the water up the discharge pipe (*c*)." It works day and night without needing attention, and will raise water to any height or distance, without

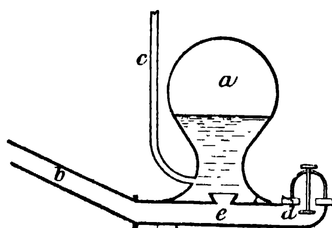


Fig. 32.

cost for labour or motive power, where a few feet fall can be obtained. With the same quantity of water and fall to work it as the water-wheel and pump, the ram will send up double the quantity of water that the wheel will do, and to the same height. The ram is made in sizes to raise from 300 to 100,000 gallons per day, and will force to a height of 1,500 feet. It raises a part of the same water that works it, or will raise pure water from a well or spring, whilst worked from a stream of impure water. Our illustration (Fig. 33) shows a ram, erected by Messrs. S. Owen and Sons, supplied by a fall of water from a lake, and



Fig. 33.

forcing up to a farm at an elevation; the waste water expended in working the ram being carried off to a lower level and into the natural channel which the overflow of the lake finds for itself. It will work when quite immersed; its cost is small to begin with; it occupies but little space; and will work for years without once stopping or needing any repairs.

The hydraulic ram is applicable where no more than 18 inches fall can be obtained, but the greater the fall the more powerful the action of the machine, and the greater the elevation to which the water can be raised. If at all possible, a fall of 8 or 10 feet should be ob-

tained. At the same time it is not advisable to use a greater fall than is absolutely necessary to raise the required quantity of water to the desired height, as the ram is then subjected to an unnecessary amount of work, the wear and tear of all the parts is increased, and the durability of the whole is proportionately decreased.

The proportion between the water raised and that running to waste depends mainly on the height of the spring or source of supply above the ram, relatively with the height to which the water is delivered. The quantity raised varies in proportion to the height to which it is conveyed with a given fall, and the length of the pipe through which the water is forced; the longer the pipe, the greater is the friction to be overcome. It is, however, not unusual to apply a ram for forcing water to a distance of 1,000 yards or more.

If the ram is fixed at a reasonable distance from the point where the water is to be delivered, the fall necessary to deliver a given quantity is approximately as follows* :—

About one-seventh part of the water will be raised to five times the height of the fall, and so on in the same proportion.

Thus, if the ram be placed under a head or fall of 10 feet, and the stream delivers 50 gallons per minute, about 7 gallons per minute can be raised to a height of 50 feet, or 3½ gallons to a height of 100 feet; or, in other words, an efficiency of 70 per cent. is obtained. Some of the improved forms of ram show, we believe, considerably greater efficiency than this.

The ram should be fixed in a pit 2 or 3 feet deep, sufficient to protect it from frost, and a race should be

* Appleby, "Handbook of Machinery."

cut to convey the waste water away. The pipes should also be laid at such a depth in the ground that they are out of the reach of the severest frost.

The cost of raising water by means of a hydraulic ram will depend on the quantity of water to be raised, the height to which it has to be forced, and the length of piping. Mr. Wheeler gives particulars of rams fixed for the supply of houses and gardens, varying from £92 10s., with a lift of 200 feet and 1,800 feet of piping, and yielding 1,400 gallons in 24 hours; to £26 for 273 feet of piping and 1,700 gallons.

CHAPTER XVI.

WATER-SUPPLY FOR LIVE STOCK AND FOR AGRICULTURAL MACHINERY.

In the earlier chapters of this work attention has been drawn to the need of water in the economy of plant life and growth, and to its use in irrigating land for the supply of those wants. The amount of water necessary for irrigation works may be greater than the requirements for other agricultural purposes, but assuredly not more important. For the live stock of the farm the need of water is more urgent than for irrigation, and the dependence of live stock on artificial supplies is more incessant. Whether in the fields or in the yards, water is a first necessity in summer, and also in the yards during winter. Only those who have had experience of stock-keeping on a large scale in waterless regions, where there is little or no rainfall during many months of the year, can realise the full importance of this part of our subject. The water-supply for agricultural engines is now only of secondary importance, and water-power for driving threshing or any other machines, if not an absolute necessity, is certainly a very great economy and advantage in many situations.

Water for Stock in the Fields.—A supply of good water for stock during the summer months is an essential requisite in all pasture fields. Horses and cattle require on the average about five gallons each per

day, and a sheep about half a gallon per day in dry weather. On waterless formations, therefore, any means of rendering water easily come at does much to enhance the value of the land for grazing purposes.

The plans usually adopted are either to sink deep wells or to form reservoirs or drinking-ponds. If a well is sunk in the corner of a field where two fences cross, one trough may be made to serve for watering the stock in four fields; and if the well has plenty of water, pipes may be laid to carry part of it to other fields, which will be found cheaper than sinking more wells. When a pump is necessary, the water-trough for the stock should not be placed immediately under the pump-spout, but some feet distant, a piece of tubing being employed to convey the water. The pump itself should be fenced off so that cattle and horses cannot reach it.

Millions of acres in Central Australia, which for years have been considered uninhabitable, have been turned into fertile country by the aid of artesian wells and catch-water reservoirs. The country in parts is fairly watered, but wells are everywhere necessary to supplement the supply from the creeks. Those squatters who recognise this fact are doing well. The most valuable run, Tarella station, carries 60,000 sheep, the owner having constructed eight dams, averaging 10,000 cubic yards each, on the Bunker Creek. Not content with this, he sank three artesian wells at different spots, one of which is sufficient for the requirements of 20,000 sheep, whilst each of the others yields 3,000 gallons of water a day. A new artesian well at Sale, with its overflow of 400,000 gallons of water a day, rising 12 feet above the surface, is a great success. The recent sinking of an artesian well by Mr. De

Renzil Wilson, on Tatara Run, near Curriwillinghi, on the New South Wales side of the Queensland boundary, where at the depth of 200 feet a spring was tapped which forced itself to the height of 15 feet above the surface, and at the estimated rate of 500 gallons per minute, is even more successful.

Field ponds answer very well in localities where no other means of coming at water for stock is available. These are simply small reservoirs or receptacles for collecting water, and are dug out of the ground. They are usually made circular in plan, and so situated that they furnish a supply to four fields.

It need never be very difficult to make a pond in a clayey soil, which is itself retentive of water. Where ponds are made in a porous soil, much more care is necessary. The bottom and sides must then be covered with a thick coat of the toughest clay, from a foot to two feet thick, well rammed down. There is the greatest difficulty in finding water in chalky soils, because these are not in themselves very retentive of it, and generally lie in such beds that it is impracticable to dig through them. But even here ponds are easily made by digging into the chalk, and lining them with a coat of clay, as before directed. Some farmers judiciously pave the declivity by which the cattle approach the pond, and this renders it much more lasting than it would be, and preserves the water clean, while others pave the whole pond.

There are different methods of constructing ponds, but the plan adopted is generally this: The ground plan is circular, and usually 40 or 45 feet in diameter, with a centre depth of about 5 feet. This hole being dug out, a layer of clay, sufficiently moistened, is trodden down to the depth of a foot. Upon this a layer of quick-lime, an inch or more in thickness, is

spread; and above that another layer of clay, a foot thick, is trodden and rammed as before. The use of the lime is to prevent worms penetrating through the clay in dry weather. A pond of the above dimensions will cost from £8 to £12.

Formerly the price of making a pond 60 feet in diameter was £10. A circle 60 feet in diameter contains an area of 314 square yards; so that each square yard of surface cost at this rate 7½d. And the capacity of such a pond, 6 feet deep in centre, is 209·4 cubic yards, each of which must have cost in the above instance 11½d. Five pounds have been given for a pond 36 feet in diameter, which is 10½d. each square yard of surface; and supposing it 4 feet deep at the centre, 2s. each cubic yard. It is plain from these figures that the larger the pond the less in proportion is the expense.

Water for Stock in the Yards.—Where a supply cannot be drawn from springs or running streams, recourse should be had to deep wells or to rain-water tanks. Ponds and open watering-places about the farmyard are very objectionable, as the water in them is always more or less polluted from yard drainage and from trampling by cattle. In many places driven or bored wells are now erected within the buildings, and even where the supply has to be brought a considerable distance from running springs, the employment of pipes enables water to be laid on to every stall in the yards if necessary, and at a comparatively small cost. The boon of this can only be appreciated by those farmers who have tried it. Not only is less labour entailed in tending the stock, but the animals themselves thrive better than when they are driven out to drink in all sorts of weather, and left standing in the pond, or hanging about the yard-gates to catch a chill.

The roofs of all farm buildings are, or ought to be, spouted; and if the rain-water from the roofs is collected, it will in most cases be found more than sufficient not only for the supply of the farm stock, but also for threshing purposes. Rain-water from the roofs, if stored in cool brick tanks, will keep sweet and fresh for any length of time and in any climate. We have pursued this plan in the tropics for a number of years, and though it was our only supply for domestic use, never had reason to complain of the water. Every 1,000 square feet of roofing, with a rainfall of 32 inches, will yield over 16,000 gallons of water per annum; and as the buildings on an average farm afford at least four times that amount of roof surface, it is evident there need be no lack of water about the farmyard. At the above rate, 4,000 square feet of roofing would supply 64,000 gallons of water per annum, or 175 gallons per day. But the consumption of water at the yards, on an average-sized farm, would be very much less than that. The cattle would be in the pastures all summer, and the horses also, perhaps; so that the summer consumption of water by live stock, in an ordinary farmyard, would never be likely to exceed 50 gallons per day. The brick tanks or cisterns should be large enough to contain a supply for eight months. Rain-water stored in barrels, especially open-headed barrels, is not fit for animals to drink. A plentiful supply of good water for live stock all through the dry summer weather, laid on both to fields and yards by supply pipes, troughs and ball cocks, instead of having to cart it very often from a distance, is so great a boon that no farmer would object to pay 5 per cent. on the necessary outlay.

Water for Agricultural Machinery.—Another reason for a good water supply to every field is the increasing

use of steam power in cultivating the soil. Every acre of land cultivated by steam requires about 100 gallons of water for engine use. A 20-acre field requires 2,000 gallons. The convenience, not to say the economy, of having this supply at hand in the field itself is very great. On all recently laid-out farms, where steam cultivation has been introduced, much attention has been given to this point. Where springs, brooks, or drinking ponds are not accessible at every site likely to be occupied by the engines in cultivating an entire farm, tanks or wells should be provided. A tank placed in a corner where four fields meet would usually serve for all the fields, as in the case of a drinking pond so placed.

On the majority of farms, where the fields are tile-drained, the drainage-water may be led into tanks or cisterns and stored in sufficient quantity, not only for the use of the engines employed in steam cultivation, but also for watering the live stock, and sometimes even for working a water-wheel or turbine. Messrs. Howard, on their Bedfordshire farm, have so planned the drainage that it supplies a tank or pond at every point occupied by the engine engaged in tilling any part of the farm; and at the farmyard a reservoir has been excavated in the clay which holds half a million gallons of water. Extensive application of drainage-water has also been made on the estates of Lord Hatherton, in Staffordshire. In this case several ponds are used for storing the water, which is first carried to the farmyard and employed to drive a water-wheel which does all the threshing, &c., in addition to driving a saw-mill. After this, the water is passed to meadows on a lower level, where it is used in extensive and profitable irrigation.

CHAPTER XVII.

WATER-SUPPLY TO DWELLINGS.

IMPORTANT though it is to secure a good supply of water for irrigating crops, for watering live stock, and for driving machinery, the wants of the farmhouse itself, and of the cottages, are, in this respect, still greater. Water is one of the prime necessaries of life, and should be not only abundant but good. It is estimated that an adult consumes, on an average, about half an ounce daily for each pound weight of the body: therefore, a man weighing 150 pounds will require 75 ounces daily; about 50 ounces in drink and the remainder in the food. Unless, at the same time, the water consumed is good, a perfectly healthy condition of the system cannot be maintained; and it is well known that disease, in some of its most dangerous forms, is often introduced through the agency of bad water. Of course large supplies of water must be provided for domestic purposes beyond the quantities actually necessary to be consumed in food and drink.

Quantity required.—"The minimum quantity that is sufficient for the supply of a cottage or small farm-house, for all ordinary domestic purposes, may be taken at 13¾ gallons per day, allowing 5½ persons as the average number to a house, and 2½ gallons for each

person. This, of course, gives no margin for water-closets, baths, or other similar luxuries, which belong only to a larger class of dwelling. This quantity may appear small; but, having made extensive inquiry amongst cottagers and others, I found sufficient evidence to satisfy myself that it was the full quantity that was used when the water had to be baled or pumped from a tank, and not left to run to waste from a tap. Mr. Easton, in his evidence before the Select Committee on the Public Health Amendment Act of 1878, stated that, as the result of his experience and inquiries amongst cottagers in Sussex, he was satisfied that this quantity was sufficient. Colonel Cox put the quantity at 3 gallons a day, and the other witnesses agreed with the estimates of Mr. Easton and Colonel Cox, some even putting it at less. In the Sixth Report of the Rivers Pollution Commissioners is given an instance of four cottages, provided with a tank, in which the rain-water was collected from the roofs—one of the inhabitants being a laundress, who used a large quantity of water, and another feeding a number of pigs. The size of this tank was barely sufficient to give 10 gallons a day to each cottage; yet it is stated that it had never failed to maintain a sufficient supply.

"The large quantity used in towns—varying from 20 to 30 gallons a head—is due partly to manufactories, street watering, and flushing sewers; but, principally, to waste. This is proved by the fact, that towns supplied by meter do not average more than 7 gallons a head; and by the test applied to several streets in Brighton, where it was found that the supply did not average more than $4\frac{3}{4}$ gallons a head, although the number of persons to a house would be above

the average, and water-closets and baths be freely used."*

Professor Rankine† gives as a fair estimate of the daily demand for water, per inhabitant, for different purposes, the following, based upon British water supply and consumption:—

	Imperial gallons per day.		
	Least.	Average.	Greatest.
Used for domestic purposes	7	10	15
Washing streets, extinguishing fires, supplying fountains, &c.	3	3	3
Trade and manufactures	7	7	7
Waste under careful regulations, say	2	2	2½
Totals	19	22	27½

Sources of Supply.—Water, as ordinarily used for drinking purposes, is obtained from either springs, wells, lakes, or rivers, or from stored rain-water or land drainage. Where none of the other sources are available, the rain-water falling on the roofs of the houses, if collected, filtered, and stored in underground tanks, will furnish an ample and perfectly good supply.

"Granting," says Mr. Wheeler, "that 2½ gallons per head per day is enough for all the ordinary domestic requirements of a cottage, sufficient rain falls on the roof of every house in the course of a year, if properly stored, to yield a full supply. A cottage with its outbuildings covers about 500 square feet of ground. Taking the rainfall at 22 inches per annum, the quantity that may be relied on as an average in the driest districts of the country, a slated roof will yield 5,700 gallons—nearly equal to a daily supply of 15½ gallons, or rather more than 2¾ gallons per head. Tiled roofs

* Mr. Wheeler, C.E., "Universal Conference on National Water-Supply," 1879.

† "Civil Engineering."

would yield less than this, being more porous than slates. Thatched roofs may be considered as altogether unsuitable for the collection of rain-water, from their absorbent nature, the difficulty of providing spouting, and the chance of pollution from the organic matter in the decaying straw."

Where rain-water from the roofs is the only supply, the minimum size of the tanks to be provided becomes an important question. It is usually reckoned that the impounding tanks or reservoirs should contain four months' supply in the rainy districts and six months' supply in the dry districts of England. Thus a tank for a cottage, where the daily consumption is 14 gallons, would require to hold from 1,680 to 2,548 gallons.

At the Reading Meeting of the Royal Agricultural Society of England last year, Mr. C. G. Roberts, Haslemere, Surrey, exhibited a very ingenious apparatus for collecting pure rain-water from the roofs of buildings. The apparatus, which is entirely self-acting, consists of a separator, the function of which is to reject the bad and store the good water, by preventing the first portion of the rainfall (which washes and brings down from the roof or gutters all kinds of impurities) from passing into the storage tank. The first water from the roofs when a shower falls is directed into the waste-pipe; then the separator cants, and turns the pure water into the storage tank. An illustration of this apparatus appears in the Journal of the Society, vol. xviii., part 2.

Impurities in Water.—Water may be very good for irrigation purposes and yet utterly unfit for household use. The most wholesome waters, as a rule, are spring water, deep-well water, and upland surface water; and the most dangerous ones are river water, to which sewage gains access, and shallow-well water. Stored

rain-water, especially that gathered in large towns and cities, where smoke from innumerable chimneys taints the air, and the surface water from cultivated land, are of "doubtful" quality.

Rain-water is more pure than any other water before its descent, and it is only in large towns or cities where it becomes contaminated by atmospheric impurities, and is rendered unfit for use in the condition in which it falls. It is generally termed *soft*, in contradistinction to spring water, which is considered *hard*. The softness, which consists in a solvent action upon the fatty substance of the skin, is owing to a small amount of carbonate of ammonia, which is formed in the atmosphere and precipitated with the water.

Spring water and deep-well water, when impure, are usually so from the excess of inorganic matter, with which occasionally they rise highly charged. These admixtures are derived from the ground through which the water flows. The incrustations which form in steam boilers are caused by the precipitation of the impurities, in consequence of the concentration of the water in the boiler. They may be effectually removed, no matter what their nature, by boiling charcoal in the water, or by gently heating the water and filtering it through charcoal.

Pond water and shallow-well water is often full of animalcula, sewage, vegetable matter, sediment, &c.

The water from mountain streams and rivulets is always purer than that from low grounds, because the water from high lands runs rapidly, and generally over gravelled beds. River water from low grounds is generally rendered impure by the presence of organic matter generated in sewers and drains, and thence discharged. Almost every gallon of such water contains

a quantity of spores, seeds, or ova of vegetable and animal organisms, and if a bottle of it is allowed to stand by for a short time a sediment is thrown down in which a number of creatures will be discovered by the microscope. Water of this sort is unwholesome and dangerous, whether it contains the actual carriers of disease or not.

Filtration.—In all towns where water-works exist the water supplied has already undergone filtration through sand and gravel, which is the only plan available for companies dealing with such immense quantities of water. One square yard of filter-bed should be provided for each 700 gallons required in 24 hours, and the filter-bed should be 6 feet in total depth, composed as follows: 30 inches of fine sand, 6 inches of coarse sand, 6 inches of shells, 30 inches of gravel. Perforated pipes should traverse the bottom of filter-beds to collect the filtered water, and the fine sand forming the top stratum should be frequently renewed.

The sand and gravel filter, however, is not sufficient, nor has it the power to remove a deal of the animalcula and other injurious matters often contained in the water. River water thus filtered may be none the less unwholesome because it is made clearer. Every one knows that the liquid evacuations of both men and animals is often clear, and can be readily passed through a stratum of coarse sand, but the liquid is not less free from sewage after being so passed. This filtration at best can only be looked upon as a means of removing the grosser impurities. It is therefore imperative that the water should undergo another and more complete filtering process before it can be considered fit for drinking, such as passing it through certain media which have the power of thoroughly purifying the

water by oxidizing the organic matter and changing chemically the impurities in solution.

The Registrar-General most strongly recommends the adoption of a system of domestic filtration, every consumer employing upon his own premises suitable means to purify the water required for his use. He also recommends that householders should obtain real water purifiers, and not mere strainers. The old-fashioned system of passing water merely through balls or slabs of charcoal, or material which has the appearance of being charcoal, worked into a solid form, is for the most part useless for the proper filtration of water.

The best filters are constructed entirely with pure charcoal, and remove lead, lime, and sewage from water. They are also self-cleansing.

In Fig. 34 we have an illustration of Lipscombe's Self-cleansing Charcoal Cistern Filter. The drawing represents a filter and pure water reservoir inside an ordinary house cistern, but they may be modified to suit any cistern or tank above or under ground. The impure water passes through the inlet into chamber of filter, thence upwards through a plate, usually of porous stone, represented by the dotted line, then through powerful purified charcoal into the pure water reservoir, from which it may be drawn off cold by the pure-water tap, or hot and pure from the boiler.

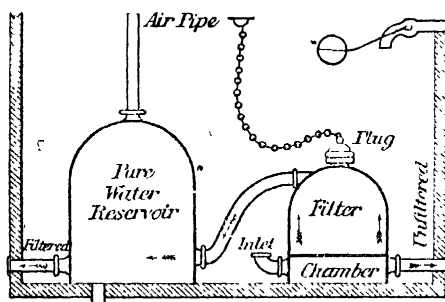


Fig. 34.

INDEX.

THE END.

PRINTED BY J. S. VIRTUE AND CO., LIMITED, CITY ROAD, LONDON.

Weale's Rudimentary Series.



LONDON, 1862.

THE PRIZE MEDAL

Was awarded to the Publishers of

"WEALE'S SERIES."



A NEW LIST OF

WEALE'S SERIES

RUDIMENTARY SCIENTIFIC, EDUCATIONAL, AND CLASSICAL.

Comprising nearly Three Hundred and Fifty distinct works in almost every department of Science, Art, and Education, recommended to the notice of Engineers, Architects, Builders, Artisans, and Students generally, as well as to those interested in Workmen's Libraries, Literary and Scientific Institutions, Colleges, Schools, Science Classes, &c., &c.

☞ "WEALE'S SERIES includes Text-Books on almost every branch of Science and Industry, comprising such subjects as Agriculture, Architecture and Building, Civil Engineering, Fine Arts, Mechanics and Mechanical Engineering, Physical and Chemical Science, and many miscellaneous Treatises. The whole are constantly undergoing revision, and new editions, brought up to the latest discoveries in scientific research, are constantly issued. The prices at which they are sold are as low as their excellence is assured."—*American Literary Gazette.*

"Amongst the literature of technical education, WEALE'S SERIES has ever enjoyed a high reputation, and the additions being made by Messrs. CROSBY LOCKWOOD & CO render the series even more complete, and bring the information upon the several subjects down to the present time."—*Mining Journal.*

"It is not too much to say that no books have ever proved more popular with, or more useful to, young engineers and others than the excellent treatises comprised in WEALE'S SERIES."—*Engineer.*

"The excellence of WEALE'S SERIES is now so well appreciated, that it would be wasting our space to enlarge upon their general usefulness and value."—*Builder.*

"WEALE'S SERIES has become a standard as well as an unrivalled collection of treatises in all branches of art and science."—*Public Opinion.*



PHILADELPHIA, 1876.

THE PRIZE MEDAL

Was awarded to the Publishers for

Books: Rudimentary, Scientific,

"WEALE'S SERIES," ETC.



CROSBY LOCKWOOD & SON,

7, STATIONERS' HALL COURT, LUDGATE HILL, LONDON, E.C.

WEALE'S RUDIMENTARY SCIENTIFIC SERIES.



*** The volumes of this Series are freely Illustrated with Woodcuts, or otherwise, where requisite. Throughout the following List it must be understood that the books are bound in limp cloth, unless otherwise stated; *but the volumes marked with a ‡ may also be had strongly bound in cloth boards for 6d. extra.*

N.B.—In ordering from this List it is recommended, as a means of facilitating business and obviating error, to quote the numbers affixed to the volumes, as well as the titles and prices.

CIVIL ENGINEERING, SURVEYING, ETC.

No.

31. *WELLS AND WELL-SINKING.* By JOHN GEO. SWINDELL, A.R.I.B.A., and G. R. BURNELL, C.E. Revised Edition. With a New Appendix on the Qualities of Water. Illustrated. 2s.

35. *THE BLASTING AND QUARRYING OF STONE,* for Building and other Purposes. With Remarks on the Blowing up of Bridges. By Gen. Sir JOHN BURGOYNE, Bart., K.C.B. Illustrated. 1s. 6d.

43. *TUBULAR, AND OTHER IRON GIRDER BRIDGES,* particularly describing the Britannia and Conway Tubular Bridges. By G. DRYSDALE DEMPSEY, C.E. Fourth Edition. 2s.

44. *FOUNDATIONS AND CONCRETE WORKS,* with Practical Remarks on Footings, Sand, Concrete, Béton, Pile-driving, Caissons, and Cofferdams, &c. By E. DOBSON. Fifth Edition. 1s. 6d.

60. *LAND AND ENGINEERING SURVEYING.* By T. BAKER, C.E. Fourteenth Edition, revised by Professor J. R. YOUNG. 2s.‡

80*. *EMBANKING LANDS FROM THE SEA.* With examples and Particulars of actual Embankments, &c. By J. WIGGINS, F.G.S. 2s.

81. *WATER WORKS,* for the Supply of Cities and Towns. With a Description of the Principal Geological Formations of England as influencing Supplies of Water; and Details of Engines and Pumping Machinery for raising Water. By SAMUEL HUGHES, F.G.S., C.E. New Edition. 4s.‡

118. *CIVIL ENGINEERING IN NORTH AMERICA,* a Sketch of. By DAVID STEVENSON, F.R.S.E., &c. Plates and Diagrams. 3s.

167. *IRON BRIDGES, GIRDERS, ROOFS, AND OTHER WORKS.* By FRANCIS CAMPIN, C.E. 2s. 6d.‡

197. *ROADS AND STREETS (THE CONSTRUCTION OF).* By HENRY LAW, C.E., revised and enlarged by D. K. CLARK, C.E., including pavements of Stone, Wood, Asphalte, &c. 4s. 6d.‡

203. *SANITARY WORK IN THE SMALLER TOWNS AND IN VILLAGES.* By C. SLAGG, A.M.I.C.E. Revised Edition. 3s.‡

212. *GAS-WORKS, THEIR CONSTRUCTION AND ARRANGEMENT;* and the Manufacture and Distribution of Coal Gas. Originally written by SAMUEL HUGHES, C.E. Re-written and enlarged by WILLIAM RICHARDS, C.E. Seventh Edition, with important additions. 5s. 6d.‡

213. *PIONEER ENGINEERING.* A Treatise on the Engineering Operations connected with the Settlement of Waste Lands in New Countries. By EDWARD DOBSON, Assoc. Inst. C.E. 4s. 6d.‡

216. *MATERIALS AND CONSTRUCTION;* A Theoretical and Practical Treatise on the Strains, Designing, and Erection of Works of Construction. By FRANCIS CAMPIN, C.E. Second Edition, revised. 3s.‡

219. *CIVIL ENGINEERING.* By HENRY LAW, M.Inst. C.E. Including HYDRAULIC ENGINEERING by GEO. R. BURNELL, M.Inst. C.E. Seventh Edition, revised, with large additions by D. KINNEAR CLARK, M.Inst. C.E. 6s. 6d., Cloth boards, 7s. 6d.

☞ *The ‡ indicates that these vols. may be had strongly bound at 6d. extra.*

MECHANICAL ENGINEERING, ETC.

33. *CRANES*, the Construction of, and other Machinery for Raising Heavy Bodies. By JOSEPH GLYNN, F.R.S. Illustrated. 1s. 6d.

34. *THE STEAM ENGINE*. By Dr. LARDNER. Illustrated. 1s. 6d.

59. *STEAM BOILERS:* their Construction and Management. By R. ARMSTRONG, C.E. Illustrated. 1s. 6d.

82. *THE POWER OF WATER*, as applied to drive Flour Mills, and to give motion to Turbines, &c. By JOSEPH GLYNN, F.R.S. 2s.‡

98. *PRACTICAL MECHANISM*, the Elements of; and Machine Tools. By T. BAKER, C.E. With Additions by J. NASMYTH, C.E. 2s. 6d.‡

139. *THE STEAM ENGINE*, a Treatise on the Mathematical Theory of, with Rules and Examples for Practical Men. By T. BAKER, C.E. 1s. 6d.

164. *MODERN WORKSHOP PRACTICE*, as applied to Steam Engines, Bridges, Cranes, Ship-building, &c. By J. G. WINTON. 3s.‡

165. *IRON AND HEAT*, exhibiting the Principles concerned in the Construction of Iron Beams, Pillars, and Girders. By J. ARMOUR. 2s. 6d.‡

166. *POWER IN MOTION:* Horse-Power, Toothed-Wheel Gearing, Long and Short Driving Bands, and Angular Forces. By J. ARMOUR, 2s.‡

171. *THE WORKMAN'S MANUAL OF ENGINEERING* DRAWING. By J. MAXTON. 6th Edn. With 7 Plates and 350 Cuts. 3s. 6d.‡

190. *STEAM AND THE STEAM ENGINE*, Stationary and Portable. (Being an Extension of the Elementary Treatise on the Steam Engine of Mr. John Sewell.) By D. K. CLARK, M.I.C.E. 3s. 6d.‡

200. *FUEL*, its Combustion and Economy. By C. W. WILLIAMS, With Recent Practice in the Combustion and Economy of Fuel—Coal, Coke, Wood, Peat, Petroleum, &c.—by D. K. CLARK, M.I.C.E. 3s. 6d.‡

202. *LOCOMOTIVE ENGINES*. By G. D. DEMPSEY, C.E.; with large additions by D. KINNEAR CLARK, M.I.C.E. 3s.‡

211. *THE BOILERMAKER'S ASSISTANT* in Drawing, Templating, and Calculating Boiler and Tank Work. By JOHN COURTNEY. Practical Boiler Maker. Edited by D. K. CLARK, C.E. 100 Illustrations. 2s.

217. *SEWING MACHINERY:* Its Construction, History, &c., with full Technical Directions for Adjusting, &c. By J. W. URQUHART, C.E. 2s.‡

223. *MECHANICAL ENGINEERING*. Comprising Metallurgy, Moulding, Casting, Forging, Tools, Workshop Machinery, Manufacture of the Steam Engine, &c. By FRANCIS CAMPIN, C.E. Second Edition. 2s. 6d.‡

236. *DETAILS OF MACHINERY*. Comprising Instructions for the Execution of various Works in Iron. By FRANCIS CAMPIN, C.E. 3s.‡

237. *THE SMITHY AND FORGE;* including the Farrier's Art and Coach Smithing. By W. J. E. CRANE. Illustrated. 2s. 6d.‡

238. *THE SHEET-METAL WORKER'S GUIDE;* a Practical Handbook for Tinsmiths, Coppersmiths, Zincworkers, &c. With 94 Diagrams and Working Patterns. By W. J. E. CRANE. Second Edition, revised. 1s. 6d.

251. *STEAM AND MACHINERY MANAGEMENT:* with Hints on Construction and Selection. By M. POWIS BALE, M.I.M.E. 2s. 6d.‡

254. *THE BOILERMAKER'S READY-RECKONER*. By J. COURTNEY. Edited by D. K. CLARK, C.E. 4s., limp; 5s., half-bound.

255. *LOCOMOTIVE ENGINE-DRIVING*. A Practical Manual for Engineers in charge of Locomotive Engines. By MICHAEL REYNOLDS, M.S.E. Eighth Edition. 3s. 6d., limp; 4s. 6d. cloth boards.

256. *STATIONARY ENGINE-DRIVING*. A Practical Manual for Engineers in charge of Stationary Engines. By MICHAEL REYNOLDS, M.S.E. Third Edition. 3s. 6d. limp; 4s. 6d. cloth boards.

260. *IRON BRIDGES OF MODERATE SPAN:* their Construction and Erection. By HAMILTON W. PENDRED, late Inspector of Ironwork to the Salford Corporation. 2s. [*Just published.*

☞ *The ‡ indicates that these vols. may be had strongly bound at 6d. extra.*

MINING, METALLURGY, ETC.

4. *MINERALOGY,* Rudiments of; a concise View of the General Properties of Minerals. By A. RAMSAY, F.G.S., F.R.G.S, &c. Third Edition, revised and enlarged. Illustrated. 3s. 6d.‡

117. *SUBTERRANEOUS SURVEYING,* with and without the Magnetic Needle. By T. FENWICK and T. BAKER, C.E. Illustrated. 2s. 6d.‡

133. *METALLURGY OF COPPER;* an Introduction to the Methods of Seeking, Mining, and Assaying Copper, and Manufacturing its Alloys By ROBERT H. LAMBORN, Ph.D. Woodcuts. 2s. 6d.‡

135. *ELECTRO-METALLURGY;* Practically Treated. By ALEXANDER WATT, F.R.S.S.A. Eighth Edition, revised, with additional Matter and Illustrations, including the most recent Processes. 3s.‡

172. *MINING TOOLS,* Manual of. For the Use of Mine Managers, Agents, Students, &c. By WILLIAM MORGANS. 2s. 6d.‡

172*. *MINING TOOLS, ATLAS* of Engravings to Illustrate the above, containing 235 Illustrations, drawn to Scale. 4to. 4s. 6d.; cloth boards, 6s.

176. *METALLURGY OF IRON.* Containing History of Iron Manufacture, Methods of Assay, and Analyses of Iron Ores, Processes of Manufacture of Iron and Steel, &c. By H. BAUERMAN, F.G.S. Fifth Edition revised and enlarged. 5s.‡

180. *COAL AND COAL MINING.* By WARINGTON W. SMYTH, M.A., F.R.S. Sixth Edition, revised. 3s. 6d.‡

195. *THE MINERAL SURVEYOR AND VALUER'S COMPLETE GUIDE.* Comprising a Treatise on Improved Mining Surveying and the Valuation of Mining Properties, with new Traverse Tables. By W. LINTERN, Mining Engineer. Second Edition, with an Appendix on Magnetic and Angular Surveying, with Records of the Peculiarities of Needle Disturbances. With Four Plates of Diagrams, &c. 3s 6d.‡ [*Just published*

214. *SLATE AND SLATE QUARRYING,* Scientific, Practical, and Commercial. By D. C. DAVIES, F.G.S., Mining Engineer, &c. 3s.‡

ARCHITECTURE, BUILDING, ETC.

16. *ARCHITECTURE—ORDERS*—The Orders and their Æsthetic Principles. By W. H. LEEDS. Illustrated. 1s. 6d.

17. *ARCHITECTURE—STYLES*—The History and Description of the Styles of Architecture of Various Countries, from the Earliest to the Present Period. By T. TALBOT BURY, F.R.I.B.A., &c. Illustrated. 2s.
*** ORDERS AND STYLES OF ARCHITECTURE, *in One Vol.*, 3*s.* 6*d.*

18. *ARCHITECTURE—DESIGN*—The Principles of Design in Architecture, as deducible from Nature and exemplified in the Works of the Greek and Gothic Architects. By E. L. GARBETT, Architect. Illustrated. 2s 6d.
*** *The three preceding Works, in One handsome Vol., half bound, entitled* "MODERN ARCHITECTURE," *price* 6s.

22. *THE ART OF BUILDING,* Rudiments of. General Principles of Construction, Materials used in Building, Strength and Use of Materials, Working Drawings, Specifications, and Estimates. By E. DOBSON, 2s.‡

25. *MASONRY AND STONECUTTING:* Rudimentary Treatise on the Principles of Masonic Projection and their application to Construction. By EDWARD DOBSON, M.R.I.B.A., &c. 2s. 6d.‡

42. *COTTAGE BUILDING.* By C. BRUCE ALLEN, Architect. Tenth Edition, revised and enlarged. With a Chapter on Economic Cottages for Allotments, by EDWARD E. ALLEN, C.E. 2s.

45. *LIMES, CEMENTS, MORTARS, CONCRETES, MASTICS,* PLASTERING, &c. By G. R. BURNELL, C.E. Thirteenth Edition. 1s. 6d.

☞ *The ‡ indicates that these vols. may be had strongly bound at* 6*d. extra.*

Architecture, Building, etc., *continued.*

57. *WARMING AND VENTILATION.* An Exposition of the General Principles as applied to Domestic and Public Buildings, Mines, Lighthouses, Ships, &c. By C. TOMLINSON, F.R.S., &c. Illustrated. 3s.

111. *ARCHES, PIERS, BUTTRESSES, &c.:* Experimental Essays on the Principles of Construction. By W. BLAND. Illustrated. 1s. 6d.

116. *THE ACOUSTICS OF PUBLIC BUILDINGS;* or, The Principles of the Science of Sound applied to the purposes of the Architect and Builder. By T. ROGER SMITH, M.R.I.B A., Architect. Illustrated. 1s. 6d.

127. *ARCHITECTURAL MODELLING IN PAPER,* the Art of. By T. A. RICHARDSON, Architect. Illustrated. 1s. 6d.

128. *VITRUVIUS—THE ARCHITECTURE OF MARCUS VITRUVIUS POLLO.* In Ten Books. Translated from the Latin by JOSEPH GWILT, F.S A., F.R.A.S. With 23 Plates. 5s.

130. *GRECIAN ARCHITECTURE,* An Inquiry into the Principles of Beauty in; with an Historical View of the Rise and Progress of the Art in Greece. By the EARL OF ABERDEEN. 1s.

*** *The two preceding Works in One handsome Vol., half bound, entitled* "ANCIENT ARCHITECTURE," *price* 6s.

132. *THE ERECTION OF DWELLING-HOUSES.* Illustrated by a Perspective View, Plans, Elevations, and Sections of a pair of Semi-detached Villas, with the Specification, Quantities, and Estimates, &c. By S. H. BROOKS. New Edition, with Plates. 2s. 6d ‡

156. *QUANTITIES & MEASUREMENTS* in Bricklayers', Masons', Plasterers', Plumbers', Painters', Paperhangers', Gilders', Smiths', Carpenters' and Joiners' Work. By A. C BEATON, Surveyor. New Edition. 1s. 6d.

175. *LOCKWOOD & CO.'S BUILDER'S AND CONTRACTOR'S* PRICE BOOK, containing the latest Prices of all kinds of Builders' Materials and Labour, and of all Trades connected with Building, &c., &c. Edited by F. T. W. MILLER, Architect. Published annually. 3s. 6d.; half bound, 4s.

182. *CARPENTRY AND JOINERY*—THE ELEMENTARY PRINCIPLES OF CARPENTRY. Chiefly composed from the Standard Work of THOMAS TREDGOLD, C.E. With a TREATISE ON JOINERY by E. WYNDHAM TARN, M.A. Fourth Edition, Revised. 3s. 6d.‡

182*. *CARPENTRY AND JOINERY. ATLAS* of 35 Plates to accompany the above. With Descriptive Letterpress. 4to. 6s.

185. *THE COMPLETE MEASURER;* the Measurement of Boards, Glass, &c.; Unequal-sided, Square-sided, Octagonal-sided, Round Timber and Stone, and Standing Timber, &c. By RICHARD HORTON. Fifth Edition. 4s.; strongly bound in leather, 5s.

187. *HINTS TO YOUNG ARCHITECTS.* By G. WIGHTWICK. New Edition. By G. H. GUILLAUME. Illustrated. 3s. 6d.‡

188. *HOUSE PAINTING, GRAINING, MARBLING, AND SIGN WRITING:* with a Course of Elementary Drawing for House-Painters, Sign-Writers, &c., and a Collection of Useful Receipts. By ELLIS A. DAVIDSON. Fifth Edition. With Coloured Plates. 5s. cloth limp; 6s. cloth boards.

189. *THE RUDIMENTS OF PRACTICAL BRICKLAYING.* In Six Sections: General Principles; Arch Drawing, Cutting, and Setting; Pointing; Paving, Tiling, Materials; Slating and Plastering; Practical Geometry, Mensuration, &c. By ADAM HAMMOND. Sixth Edition. 1s. 6d.

191. *PLUMBING.* A Text-Book to the Practice of the Art or Craft of the Plumber. With Chapters upon House Drainage. Fourth Edition. With 330 Illustrations. By W. P. BUCHAN. 3s. 6d.‡

192. *THE TIMBER IMPORTER'S, TIMBER MERCHANT'S,* and BUILDER'S STANDARD GUIDE. By R. E. GRANDY. 3s.‡

206. *A BOOK ON BUILDING, Civil and Ecclesiastical,* including CHURCH RESTORATION. With the Theory of Domes and the Great Pyramid, &c. By Sir EDMUND BECKETT, Bart., LL.D., Q.C., F.R.A S. 4s. 6d.‡

☞ *The ‡ indicates that these vols. may be had strongly bound at 6d. extra.*

Architecture, Building, etc., *continued.*

226. *THE JOINTS MADE AND USED BY BUILDERS* in the Construction of various kinds of Engineering and Architectural Works. By WYVILL J. CHRISTY, Architect. With upwards of 160 Engravings on Wood. 3s.‡

228. *THE CONSTRUCTION OF ROOFS OF WOOD AND IRON* By E. WYNDHAM TARN, M.A., Architect. Second Edition, revised. 1s. 6d

229. *ELEMENTARY DECORATION:* as applied to the Interior and Exterior Decoration of Dwelling-Houses, &c. By J. W. FACEY. 2s.

257. *PRACTICAL HOUSE DECORATION.* A Guide to the Art of Ornamental Painting, the Arrangement of Colours in Apartments, and the Principles of Decorative Design. With Remarks on the Nature and Properties of Pigments. By JAMES W. FACEY. 2s. 6d.

*** *The two preceding Works, in One handsome Vol., half-bound, entitled* "HOUSE DECORATION, ELEMENTARY AND PRACTICAL," *price* 5s.

230. *HANDRAILING.* Showing New and Simple Methods for finding the Pitch of the Plank, Drawing the Moulds, Bevelling, Jointing-up, and Squaring the Wreath. By GEORGE COLLINGS. Plates and Diagrams. 1s. 6d.

247. *BUILDING ESTATES:* a Rudimentary Treatise on the Development, Sale, Purchase, and General Management of Building Land. By FOWLER MAITLAND, Surveyor. Second Edition, revised. 2s.

248. *PORTLAND CEMENT FOR USERS.* By HENRY FAIJA, Assoc. M. Inst. C.E. Second Edition, corrected. Illustrated. 2s.

252. *BRICKWORK:* a Practical Treatise, embodying the General and Higher Principles of Bricklaying, Cutting and Setting, &c. By F. WALKER. Second Edition, Revised and Enlarged. 1s. 6d.

23. *THE PRACTICAL BRICK AND TILE BOOK.* Comprising:
189. BRICK AND TILE MAKING, by E. DOBSON, A.I.C.E.; PRACTICAL BRICKLAY-
252. ING, by A. HAMMOND; BRICKWORK, by F. WALKER. 550 pp. with 270 Illustrations. 6s. Strongly half-bound.

253. *THE TIMBER MERCHANT'S, SAW-MILLER'S, AND* IMPORTER'S FREIGHT-BOOK AND ASSISTANT. By WM. RICHARDSON. With a Chapter on Speeds of Saw-Mill Machinery, &c. By M. POWIS BALE, A.M.Inst.C.E. 3s.‡

258. *CIRCULAR WORK IN CARPENTRY AND JOINERY.* A Practical Treatise on Circular Work of Single and Double Curvature. By GEORGE COLLINGS, Author of "A Treatise on Handrailing." 2s. 6d.

259. *GAS FITTING:* A Practical Handbook treating of every Description of Gas Laying and Fitting. By JOHN BLACK. With 122 Illustrations. 2s. 6d.‡

261. *SHORING AND ITS APPLICATION:* A Handbook for the Use of Students. By GEORGE H. BLAGROVE. 1s. 6d. [*Just published.*

SHIPBUILDING, NAVIGATION, MARINE ENGINEERING, ETC.

51. *NAVAL ARCHITECTURE.* An Exposition of the Elementary Principles of the Science, and their Practical Application to Naval Construction. By J. PEAKE. Fifth Edition, with Plates and Diagrams. 3s. 6d.‡

53*. *SHIPS FOR OCEAN & RIVER SERVICE,* Elementary and Practical Principles of the Construction of. By H. A. SOMMERFELDT. 1s. 6d.

53**. *AN ATLAS OF ENGRAVINGS* to Illustrate the above. Twelve large folding plates. Royal 4to, cloth. 7s. 6d.

54. *MASTING, MAST-MAKING, AND RIGGING OF SHIPS,* Also Tables of Spars, Rigging, Blocks; Chain, Wire, and Hemp Ropes, &c., relative to every class of vessels. By ROBERT KIPPING, N.A. 2s.

54*. *IRON SHIP-BUILDING.* With Practical Examples and Details. By JOHN GRANTHAM, C.E. 5th Edition. 4s.

☞ *The ‡ indicates that these vols. may be had strongly bound at 6d. extra.*

Shipbuilding, Navigation, Marine Engineering, etc., *cont.*

55. *THE SAILOR'S SEA BOOK:* a Rudimentary Treatise on Navigation. By JAMES GREENWOOD, B.A. With numerous Woodcuts and Coloured Plates. New and enlarged edition. By W. H. ROSSER. 2s. 6d.‡

80. *MARINE ENGINES AND STEAM VESSELS.* By ROBERT MURRAY, C.E. Eighth Edition, thoroughly Revised, with Additions by the Author and by GEORGE CARLISLE, C.E., Senior Surveyor to the Board of Trade, Liverpool. 4s. 6d. limp; 5s. cloth boards.

83*bis*. *THE FORMS OF SHIPS AND BOATS.* By W. BLAND. Seventh Edition, Revised, with numerous Illustrations and Models. 1s. 6d.

99. *NAVIGATION AND NAUTICAL ASTRONOMY,* in Theory and Practice. By Prof. J. R. YOUNG. New Edition. 2s. 6d.

106. *SHIPS' ANCHORS,* a Treatise on. By G. COTSELL, N.A. 1s. 6d.

149. *SAILS AND SAIL-MAKING.* With Draughting, and the Centre of Effort of the Sails; Weights and Sizes of Ropes; Masting, Rigging, and Sails of Steam Vessels, &c. 12th Edition. By R. KIPPING, N.A. 2s 6d.‡

155. *ENGINEER'S GUIDE TO THE ROYAL & MERCANTILE NAVIES.* By a PRACTICAL ENGINEER. Revised by D. F. M'CARTHY. 3s.

55 & 204. *PRACTICAL NAVIGATION.* Consisting of The Sailor's Sea-Book. By JAMES GREENWOOD and W. H. ROSSER. Together with the requisite Mathematical and Nautical Tables for the Working of the Problems. By H. LAW, C.E., and Prof. J. R. YOUNG. 7s. Half-bound.

AGRICULTURE, GARDENING, ETC.

61*. *A COMPLETE READY RECKONER FOR THE ADMEASUREMENT OF LAND,* &c. By A. ARMAN. Third Edition, revised and extended by C. NORRIS, Surveyor, Valuer, &c. 2s.

131. *MILLER'S, CORN MERCHANT'S, AND FARMER'S READY RECKONER.* Second Edition, with a Price List of Modern Flour-Mill Machinery, by W. S. HUTTON, C.E. 2s.

140. *SOILS, MANURES, AND CROPS.* (Vol. 1. OUTLINES OF MODERN FARMING.) By R. SCOTT BURN. Woodcuts. 2s.

141. *FARMING & FARMING ECONOMY,* Notes, Historical and Practical, on. (Vol. 2. OUTLINES OF MODERN FARMING.) By R. SCOTT BURN. 3s.

142. *STOCK; CATTLE, SHEEP, AND HORSES.* (Vol. 3. OUTLINES OF MODERN FARMING.) By R. SCOTT BURN. Woodcuts. 2s. 6d.

145. *DAIRY, PIGS, AND POULTRY,* Management of the. By R. SCOTT BURN. (Vol. 4. OUTLINES OF MODERN FARMING.) 2s.

146. *UTILIZATION OF SEWAGE, IRRIGATION, AND RECLAMATION OF WASTE LAND.* (Vol. 5. OUTLINES OF MODERN FARMING.) By R. SCOTT BURN. Woodcuts. 2s. 6d.

*** *Nos.* 140-1-2-5-6, *in One Vol., handsomely half-bound, entitled* "OUTLINES OF MODERN FARMING." By ROBERT SCOTT BURN. *Price* 12s.

177. *FRUIT TREES,* The Scientific and Profitable Culture of. From the French of DU BREUIL. Revised by GEO. GLENNY. 187 Woodcuts. 3s. 6d.‡

198. *SHEEP; THE HISTORY, STRUCTURE, ECONOMY, AND DISEASES OF.* By W. C. SPOONER, M.R.V.C., &c. Fourth Edition, enlarged, including Specimens of New and Improved Breeds. 3s. 6d.‡

201. *KITCHEN GARDENING MADE EASY.* By GEORGE M. F. GLENNY. Illustrated. 1s. 6d.‡

207. *OUTLINES OF FARM MANAGEMENT, and the Organization of Farm Labour.* By R. SCOTT BURN. 2s. 6d.‡

208. *OUTLINES OF LANDED ESTATES MANAGEMENT.* By R. SCOTT BURN. 2s. 6d.‡

*** *Nos.* 207 *&* 208 *in One Vol., handsomely half bound, entitled* "OUTLINES OF LANDED ESTATES AND FARM MANAGEMENT." By R. SCOTT BURN. *Price* 6s.

The ‡ indicates that these vols. may be had strongly bound at 6d. extra.

Agriculture, Gardening, etc., *continued.*

209. *THE TREE PLANTER AND PLANT PROPAGATOR.* A Practical Manual on the Propagation of Forest Trees, Fruit Trees, Flowering Shrubs, Flowering Plants, &c. By SAMUEL WOOD. 2s.‡

210. *THE TREE PRUNER.* A Practical Manual on the Pruning of Fruit Trees, including also their Training and Renovation; also the Pruning of Shrubs, Climbers, and Flowering Plants. By SAMUEL WOOD. 2s.‡

*** *Nos. 209 & 210 in One Vol., handsomely half-bound, entitled* "THE TREE PLANTER, PROPAGATOR, AND PRUNER." By SAMUEL WOOD. *Price* 5s.

218. *THE HAY AND STRAW MEASURER:* Being New Tables for the Use of Auctioneers, Valuers, Farmers, Hay and Straw Dealers, &c. By JOHN STEELE. Fourth Edition. 2s.

222. *SUBURBAN FARMING.* The Laying-out and Cultivation of Farms, adapted to the Produce of Milk, Butter, and Cheese, Eggs, Poultry, and Pigs. By Prof. JOHN DONALDSON and R. SCOTT BURN. 3s. 6d.‡

231. *THE ART OF GRAFTING AND BUDDING.* By CHARLES BALTET. With Illustrations. 2s. 6d.‡

232. *COTTAGE GARDENING;* or, Flowers, Fruits, and Vegetables for Small Gardens. By E. HOBDAY. 1s. 6d.

233. *GARDEN RECEIPTS.* Edited by CHARLES W. QUIN. 1s. 6d.

234. *THE KITCHEN AND MARKET GARDEN.* Compiled by C. W. SHAW, Editor of "Gardening Illustrated." 3s.‡

239. *DRAINING AND EMBANKING.* A Practical Treatise, embodying the most recent experience in the Application of Improved Methods. By JOHN SCOTT, late Professor of Agriculture and Rural Economy at the Royal Agricultural College, Cirencester. With 68 Illustrations. 1s. 6d.

240. *IRRIGATION AND WATER SUPPLY.* A Treatise on Water Meadows, Sewage Irrigation, Warping, &c.; on the Construction of Wells, Ponds, and Reservoirs; and on Raising Water by Machinery for Agricultural and Domestic Purposes. By Prof. JOHN SCOTT. With 34 Illus. 1s. 6d.

241. *FARM ROADS, FENCES, AND GATES.* A Practical Treatise on the Roads, Tramways, and Waterways of the Farm; the Principles of Enclosures; and the different kinds of Fences, Gates, and Stiles. By Professor JOHN SCOTT. With 75 Illustrations. 1s. 6d.

242. *FARM BUILDINGS.* A Practical Treatise on the Buildings necessary for various kinds of Farms, their Arrangement and Construction, including Plans and Estimates. By Prof. JOHN SCOTT. With 105 Illus. 2s.

243. *BARN IMPLEMENTS AND MACHINES.* A Practical Treatise on the Application of Power to the Operations of Agriculture; and on various Machines used in the Threshing-barn, in the Stock-yard, and in the Dairy, &c. By Prof. J. SCOTT. With 123 Illustrations. 2s.

244. *FIELD IMPLEMENTS AND MACHINES.* A Practical Treatise on the Varieties now in use, with Principles and Details of Construction, their Points of Excellence, and Management. By Professor JOHN SCOTT. With 138 Illustrations. 2s.

245. *AGRICULTURAL SURVEYING.* A Practical Treatise on Land Surveying, Levelling, and Setting-out; and on Measuring and Estimating Quantities, Weights, and Values of Materials, Produce, Stock, &c. By Prof. JOHN SCOTT. With 62 Illustrations. 1s. 6d.

*** *Nos. 239 to 245 in One Vol., handsomely half-bound, entitled* "THE COMPLETE TEXT-BOOK OF FARM ENGINEERING." By Professor JOHN SCOTT. *Price* 12s.

250. *MEAT PRODUCTION.* A Manual for Producers, Distributors, &c. By JOHN EWART. 2s. 6d.‡

☞ *The ‡ indicates that these vols. may be had strongly bound at 6d. extra.*

MATHEMATICS, ARITHMETIC, ETC.

32. *MATHEMATICAL INSTRUMENTS*, a Treatise on; Their

tion, in 1 vol., Illustrated. 2s.‡ [*Just published.*

*** *In ordering the above, be careful to say, "Original Edition" (No. 32), to distinguish it from the Enlarged Edition in 3 vols. (Nos. 168-9-70.)*

76. *DESCRIPTIVE GEOMETRY*, an Elementary Treatise on; with a Theory of Shadows and of Perspective, extracted from the French of G. MONGE. To which is added, a description of the Principles and Practice of Isometrical Projection. By J. F. HEATHER, M.A. With 14 Plates. 2s.

178. *PRACTICAL PLANE GEOMETRY:* giving the Simplest Modes of Constructing Figures contained in one Plane and Geometrical Construction of the Ground. By J. F. HEATHER, M.A. With 215 Woodcuts. 2s.

83. *COMMERCIAL BOOK-KEEPING.* With Commercial Phrases and Forms in English, French, Italian, and German. By JAMES HADDON, M.A., Arithmetical Master of King's College School, London. 1s. 6d.

84. *ARITHMETIC*, a Rudimentary Treatise on: with full Explanations of its Theoretical Principles, and numerous Examples for Practice. By Professor J. R. YOUNG. Eleventh Edition. 1s. 6d.

84*. A KEY to the above, containing Solutions in full to the Exercises, together with Comments, Explanations, and Improved Processes, for the Use of Teachers and Unassisted Learners. By J. R. YOUNG. 1s. 6d.

85. *EQUATIONAL ARITHMETIC*, applied to Questions of Interest, Annuities, Life Assurance, and General Commerce; with various Tables by which all Calculations may be greatly facilitated. By W. HIPSLEY. 2s.

86. *ALGEBRA*, the Elements of. By JAMES HADDON, M.A. With Appendix, containing miscellaneous Investigations, and a Collection of Problems in various parts of Algebra. 2s.

86*. A KEY AND COMPANION to the above Book, forming an extensive repository of Solved Examples and Problems in Illustration of the various Expedients necessary in Algebraical Operations. By J. R. YOUNG. 1s. 6d.

88. *EUCLID*, THE ELEMENTS OF: with many additional Propositions
89. and Explanatory Notes: to which is prefixed, an Introductory Essay on Logic. By HENRY LAW, C.E. 2s. 6d.‡

*** *Sold also separately, viz.:—*

88. EUCLID, The First Three Books. By HENRY LAW, C.E. 1s. 6d.
89. EUCLID, Books 4, 5, 6, 11, 12. By HENRY LAW, C.E. 1s. 6d.

90. *ANALYTICAL GEOMETRY AND CONIC SECTIONS*, By JAMES HANN. A New Edition, by Professor J. R. YOUNG. 2s.‡

91. *PLANE TRIGONOMETRY*, the Elements of. By JAMES HANN, formerly Mathematical Master of King's College, London. 1s. 6d.

92. *SPHERICAL TRIGONOMETRY*, the Elements of. By JAMES HANN. Revised by CHARLES H. DOWLING, C.E. 1s.

*** *Or with "The Elements of Plane Trigonometry," in One Volume*, 2s. 6d.

93. *MENSURATION AND MEASURING.* With the Mensuration and Levelling of Land for the Purposes of Modern Engineering. By T. BAKER, C.E. New Edition by E. NUGENT, C.E. Illustrated. 1s. 6d.

101. *DIFFERENTIAL CALCULUS*, Elements of the. By W. S. B. WOOLHOUSE, F.R.A.S., &c. 1s. 6d.

102. *INTEGRAL CALCULUS*, Rudimentary Treatise on the. By HOMERSHAM COX, B.A. Illustrated. 1s.

136. *ARITHMETIC*, Rudimentary, for the Use of Schools and Self-Instruction. By JAMES HADDON, M.A. Revised by A. ARMAN. 1s. 6d.

137. A KEY TO HADDON'S RUDIMENTARY ARITHMETIC. By A. ARMAN. 1s. 6d.

☞ *The ‡ indicates that these vols. may be had strongly bound at 6d. extra.*

Mathematics, Arithmetic, etc., *continued.*

168. *DRAWING AND MEASURING INSTRUMENTS.* Including—I. Instruments employed in Geometrical and Mechanical Drawing, and in the Construction, Copying, and Measurement of Maps and Plans. II. Instruments used for the purposes of Accurate Measurement, and for Arithmetical Computations. By J. F. HEATHER, M.A. Illustrated. 1s. 6d

169. *OPTICAL INSTRUMENTS.* Including (more especially) Telescopes, Microscopes, and Apparatus for producing copies of Maps and Plans by Photography. By J. F. HEATHER, M.A. Illustrated. 1s. 6d.

170. *SURVEYING AND ASTRONOMICAL INSTRUMENTS.* Including—I. Instruments Used for Determining the Geometrical Features of a portion of Ground. II. Instruments Employed in Astronomical Observations. By J. F. HEATHER, M.A. Illustrated. 1s. 6d.

*** *The above three volumes form an enlargement of the Author's original work, "Mathematical Instruments."* (*See No. 32 in the Series.*)

168.) 169.} 170.) *MATHEMATICAL INSTRUMENTS.* By J. F. HEATHER, M A. Enlarged Edition, for the most part entirely re-written. The 3 Parts as above, in One thick Volume. With numerous Illustrations. 4s. 6d.‡

158. *THE SLIDE RULE, AND HOW TO USE IT;* containing full, easy, and simple Instructions to perform all Business Calculations with unexampled rapidity and accuracy. By CHARLES HOARE, C.E. Fifth Edition. With a Slide Rule in tuck of cover. 2s. 6d.‡

196. *THEORY OF COMPOUND INTEREST AND ANNUITIES;* with Tables of Logarithms for the more Difficult Computations of Interest, Discount, Annuities, &c. By FÉDOR THOMAN. 4s.‡

199. *THE COMPENDIOUS CALCULATOR;* or, Easy and Concise Methods of Performing the various Arithmetical Operations required in Commercial and Business Transactions; together with Useful Tables. By D. O'GORMAN. Twenty-sixth Edition, carefully revised by C. NORRIS. 3s., cloth limp; 3s. 6d., strongly half-bound in leather.

204. *MATHEMATICAL TABLES,* for Trigonometrical, Astronomical, and Nautical Calculations; to which is prefixed a Treatise on Logarithms. By HENRY LAW, C.E. Together with a Series of Tables for Navigation and Nautical Astronomy. By Prof. J. R. YOUNG. New Edition. 4s.‡

204*. *LOGARITHMS.* With Mathematical Tables for Trigonometrical, Astronomical, and Nautical Calculations. By HENRY LAW, M.Inst.C.E. New and Revised Edition. (Forming part of the above Work). 3s.

221. *MEASURES, WEIGHTS, AND MONEYS OF ALL NATIONS,* and an Analysis of the Christian, Hebrew, and Mahometan Calendars. By W. S. B. WOOLHOUSE, F.R.A.S., F.S.S. Sixth Edition. 2s.‡

227. *MATHEMATICS AS APPLIED TO THE CONSTRUCTIVE ARTS.* Illustrating the various processes of Mathematical Investigation, by means of Arithmetical and Simple Algebraical Equations and Practical Examples. By FRANCIS CAMPIN, C.E. Second Edition. 3s.‡

PHYSICAL SCIENCE, NATURAL PHILOSOPHY, ETC.

1. *CHEMISTRY.* By Professor GEORGE FOWNES, F.R.S. With an Appendix on the Application of Chemistry to Agriculture. 1s.

2. *NATURAL PHILOSOPHY,* Introduction to the Study of. By C. TOMLINSON. Woodcuts. 1s. 6d.

6. *MECHANICS,* Rudimentary Treatise on. By CHARLES TOMLINSON. Illustrated. 1s. 6d.

7. *ELECTRICITY;* showing the General Principles of Electrical Science, and the purposes to which it has been applied. By Sir W. SNOW HARRIS, F.R.S., &c. With Additions by R. SABINE, C.E., F.S.A. 1s. 6d.

7*. *GALVANISM.* By Sir W. SNOW HARRIS. New Edition by ROBERT SABINE, C.E., F.S.A. 1s. 6d.

8. *MAGNETISM;* being a concise Exposition of the General Principles of Magnetical Science. By Sir W. SNOW HARRIS. New Edition, revised by H. M. NOAD, Ph.D. With 165 Woodcuts. 3s. 6d.‡

☞ *The ‡ indicates that these vols. may be had strongly bound at 6d. extra.*

Physical Science, Natural Philosophy, etc., *continued.*

11\. *THE ELECTRIC TELEGRAPH;* its History and Progress; with Descriptions of some of the Apparatus. By R. SABINE, C.E., F.S.A. 3s.

12\. *PNEUMATICS,* including Acoustics and the Phenomena of Wind Currents, for the Use of Beginners By CHARLES TOMLINSON, F.R.S. Fourth Edition, enlarged. Illustrated. 1s. 6d. [*Just published.*

72\. *MANUAL OF THE MOLLUSCA;* a Treatise on Recent and Fossil Shells. By Dr. S. P. WOODWARD, A.L.S. Fourth Edition. With Appendix by RALPH TATE, A.L.S., F.G.S. With numerous Plates and 300 Woodcuts. 6s. 6d. Cloth boards, 7s. 6d.

96\. *ASTRONOMY.* By the late Rev. ROBERT MAIN, M.A. Third Edition, by WILLIAM THYNNE LYNN, B.A., F.R.A.S. 2s.

97\. *STATICS AND DYNAMICS,* the Principles and Practice of; embracing also a clear development of Hydrostatics, Hydrodynamics, and Central Forces. By T. BAKER, C.E. Fourth Edition. 1s. 6d.

138\. *TELEGRAPH,* Handbook of the; a Guide to Candidates for Employment in the Telegraph Service. By R. BOND. 3s.‡

173\. *PHYSICAL GEOLOGY,* partly based on Major-General PORTLOCK'S "Rudiments of Geology." By RALPH TATE, A.L.S., &c. Woodcuts. 2s.

174\. *HISTORICAL GEOLOGY,* partly based on Major-General PORTLOCK'S "Rudiments." By RALPH TATE, A.L.S., &c. Woodcuts. 2s. 6d.

173 & 174. *RUDIMENTARY TREATISE ON GEOLOGY,* Physical and Historical. Partly based on Major-General PORTLOCK'S "Rudiments of Geology." By RALPH TATE, A.L.S., F.G.S., &c. In One Volume. 4s. 6d.‡

183 & 184. *ANIMAL PHYSICS,* Handbook of. By Dr. LARDNER, D.C.L., formerly Professor of Natural Philosophy and Astronomy in University College, Lond. With 520 Illustrations. In One Vol. 7s. 6d., cloth boards.

*** *Sold also in Two Parts, as follows :—*

183\. ANIMAL PHYSICS. By Dr. LARDNER. Part I., Chapters I.—VII. 4s.

184\. ANIMAL PHYSICS. By Dr. LARDNER. Part II., Chapters VIII.—XVIII. 3s.

FINE ARTS.

20\. *PERSPECTIVE FOR BEGINNERS.* Adapted to Young Students and Amateurs in Architecture, Painting, &c. By GEORGE PYNE. 2s.

40 *GLASS STAINING, AND THE ART OF PAINTING ON GLASS.* From the German of Dr. GESSERT and EMANUEL OTTO FROMBERG. With an Appendix on THE ART OF ENAMELLING. 2s. 6d.

69\. *MUSIC,* A Rudimentary and Practical Treatise on. With numerous Examples. By CHARLES CHILD SPENCER. 2s. 6d.

71\. *PIANOFORTE,* The Art of Playing the. With numerous Exercises & Lessons from the Best Masters. By CHARLES CHILD SPENCER. 1s.6d.

69-71\. *MUSIC & THE PIANOFORTE.* In one vol. Half bound, 5s.

181\. *PAINTING POPULARLY EXPLAINED,* including Fresco, Oil, Mosaic, Water Colour, Water-Glass, Tempera, Encaustic, Miniature, Painting on Ivory, Vellum, Pottery, Enamel, Glass, &c. With Historical Sketches of the Progress of the Art by THOMAS JOHN GULLICK, assisted by JOHN TIMBS, F.S.A. Fifth Edition, revised and enlarged. 5s.‡

186\. *A GRAMMAR OF COLOURING,* applied to Decorative Painting and the Arts. By GEORGE FIELD. New Edition, enlarged and adapted to the Use of the Ornamental Painter and Designer. By ELLIS A. DAVIDSON. With two new Coloured Diagrams, &c. 3s.‡

246\. *A DICTIONARY OF PAINTERS, AND HANDBOOK FOR PICTURE AMATEURS;* including Methods of Painting, Cleaning, Relining and Restoring, Schools of Painting, &c. With Notes on the Copyists and Imitators of each Master. By PHILIPPE DARYL. 2s. 6d.‡

☞ *The ‡ indicates that these vols. may be had strongly bound at 6d. extra.*

INDUSTRIAL AND USEFUL ARTS.

23. *BRICKS AND TILES*, Rudimentary Treatise on the Manufacture of. By E. DOBSON, M.R.I.B.A. Illustrated, 3s.‡

67. *CLOCKS, WATCHES, AND BELLS*, a Rudimentary Treatise on. By Sir EDMUND BECKETT, LL.D., Q.C. Seventh Edition, revised and enlarged. 4s. 6d. limp; 5s. 6d. cloth boards.

83**. *CONSTRUCTION OF DOOR LOCKS.* Compiled from the Papers of A. C. HOBBS, and Edited by CHARLES TOMLINSON, F.R.S. 2s. 6d.

162. *THE BRASS FOUNDER'S MANUAL;* Instructions for Modelling, Pattern-Making, Moulding, Turning, Filing, Burnishing, Bronzing, &c. With copious Receipts. &c. By WALTER GRAHAM. 2s.‡

205. *THE ART OF LETTER PAINTING MADE EASY.* By J. G. BADENOCH. Illustrated with 12 full-page Engravings of Examples. 1s.

215. *THE GOLDSMITH'S HANDBOOK*, containing full Instructions for the Alloying and Working of Gold. By GEORGE E. GEE, 3s.‡

225. *THE SILVERSMITH'S HANDBOOK*, containing full Instructions for the Alloying and Working of Silver. By GEORGE E. GEE. 3s.‡

*** *The two preceding Works, in One handsome Vol., half-bound, entitled* "THE GOLDSMITH'S & SILVERSMITH'S COMPLETE HANDBOOK," 7s.

249. *THE HALL-MARKING OF JEWELLERY PRACTICALLY CONSIDERED.* By GEORGE E. GEE. 3s.‡

224. *COACH BUILDING*, A Practical Treatise, Historical and Descriptive. By J. W. BURGESS. 2s. 6d.‡

235. *PRACTICAL ORGAN BUILDING.* By W. E. DICKSON, M.A., Precentor of Ely Cathedral. Illustrated. 2s. 6d.‡

262. *THE ART OF BOOT AND SHOEMAKING*, including Measurement, Last-fitting, Cutting-out, Closing and Making. By JOHN BEDFORD LENO. Numerous Illustrations. Second Edition. 2s.‡

263. *MECHANICAL DENTISTRY:* A Practical Treatise on the Construction of the Various Kinds of Artificial Dentures, with Formulæ, Tables, Receipts, &c. By CHARLES HUNTER. Third Edition. 3s.‡

MISCELLANEOUS VOLUMES.

36. *A DICTIONARY OF TERMS used in ARCHITECTURE, BUILDING, ENGINEERING, MINING, METALLURGY, ARCHÆOLOGY, the FINE ARTS, &c.* By JOHN WEALE. Fifth Edition. Revised by ROBERT HUNT, F.R.S. Illustrated. 5s. limp; 6s. cloth boards.

50. *THE LAW OF CONTRACTS FOR WORKS AND SERVICES.* By DAVID GIBBONS. Third Edition, enlarged. 3s.‡

112.* *MANUAL OF DOMESTIC MEDICINE.* By R. GOODING, B.A., M.D. A Family Guide in all Cases of Accident and Emergency. 2s.‡

112*. *MANAGEMENT OF HEALTH.* A Manual of Home and Personal Hygiene. By the Rev. JAMES BAIRD, B.A. 1s.

150. *LOGIC*, Pure and Applied. By S. H. EMMENS. 1s. 6d.

153. *SELECTIONS FROM LOCKE'S ESSAYS ON THE HUMAN UNDERSTANDING.* With Notes by S. H. EMMENS. 2s.

154. *GENERAL HINTS TO EMIGRANTS.* 2s.

157. *THE EMIGRANT'S GUIDE TO NATAL.* By ROBERT JAMES MANN, F.R.A.S., F.M.S. Second Edition. Map. 2s.

193. *HANDBOOK OF FIELD FORTIFICATION.* By Major W. W. KNOLLYS, F.R.G.S. With 163 Woodcuts. 3s.‡

194. *THE HOUSE MANAGER:* Being a Guide to Housekeeping. Practical Cookery, Pickling and Preserving, Household Work, Dairy Management, &c. By AN OLD HOUSEKEEPER. 3s. 6d.‡

194, 112 & 112*. *HOUSE BOOK (The).* Comprising:—I. THE HOUSE MANAGER. By an OLD HOUSEKEEPER. II. DOMESTIC MEDICINE. By R. GOODING, M.D. III. MANAGEMENT OF HEALTH. By J. BAIRD. In One Vol., half-bound, 6s.

☞ *The ‡ indicates that these vols. may be had strongly bound at 6d. extra.*

EDUCATIONAL AND CLASSICAL SERIES.

HISTORY.

1. **England, Outlines of the History of;** more especially with reference to the Origin and Progress of the English Constitution. By WILLIAM DOUGLAS HAMILTON, F.S.A., of Her Majesty's Public Record Office. 4th Edition, revised. 5s.; cloth boards, 6s.

5. **Greece, Outlines of the History of;** in connection with the Rise of the Arts and Civilization in Europe. By W. DOUGLAS HAMILTON, of University College, London, and EDWARD LEVIEN, M.A., of Balliol College, Oxford. 2s. 6d.; cloth boards, 3s. 6d.

7. **Rome, Outlines of the History of:** from the Earliest Period to the Christian Era and the Commencement of the Decline of the Empire. By EDWARD LEVIEN, of Balliol College, Oxford. Map, 2s. 6d.; cl. bds. 3s. 6d.

9. **Chronology of History, Art, Literature, and Progress,** from the Creation of the World to the Present Time. The Continuation by W. D. HAMILTON, F.S.A. 3s.; cloth boards, 3s. 6d.

50. **Dates and Events in English History,** for the use of Candidates in Public and Private Examinations. By the Rev. E. RAND. 1s.

ENGLISH LANGUAGE AND MISCELLANEOUS.

11. **Grammar of the English Tongue,** Spoken and Written. With an Introduction to the Study of Comparative Philology. By HYDE CLARKE, D.C.L. Fourth Edition. 1s. 6d.

11*. **Philology:** Handbook of the Comparative Philology of English, Anglo-Saxon, Frisian, Flemish or Dutch, Low or Platt Dutch, High Dutch or German, Danish, Swedish, Icelandic, Latin, Italian, French, Spanish, and Portuguese Tongues. By HYDE CLARKE, D.C.L. 1s.

12. **Dictionary of the English Language,** as Spoken and Written. Containing above 100,000 Words. By HYDE CLARKE, D.C.L. 3s. 6d.; cloth boards, 4s 6d.; complete with the GRAMMAR, cloth bds., 5s. 6d.

48. **Composition and Punctuation,** familiarly Explained for those who have neglected the Study of Grammar. By JUSTIN BRENAN. 17th Edition. 1s. 6d.

49. **Derivative Spelling-Book:** Giving the Origin of Every Word from the Greek, Latin, Saxon, German, Teutonic, Dutch, French, Spanish, and other Languages; with their present Acceptation and Pronunciation. By J. ROWBOTHAM, F.R.A.S. Improved Edition. 1s. 6d.

51. **The Art of Extempore Speaking:** Hints for the Pulpit, the Senate, and the Bar. By M. BAUTAIN, Vicar-General and Professor at the Sorbonne. Translated from the French. 8th Edition, carefully corrected. 2s. 6d.

52. **Mining and Quarrying,** with the Sciences connected therewith. First Book of, for Schools. By J. H. COLLINS, F.G.S., Lecturer to the Miners' Association of Cornwall and Devon. 1s.

53. **Places and Facts in Political and Physical Geography,** for Candidates in Examinations. By the Rev. EDGAR RAND, B.A. 1s.

54. **Analytical Chemistry,** Qualitative and Quantitative, a Course of. To which is prefixed, a Brief Treatise upon Modern Chemical Nomenclature and Notation. By WM. W PINK and GEORGE E. WEBSTER. 2s.

THE SCHOOL MANAGERS' SERIES OF READING BOOKS,

Edited by the Rev. A. R. GRANT, Rector of Hitcham, and Honorary Canon of Ely; formerly H.M. Inspector of Schools.

INTRODUCTORY PRIMER, 3d.

	s. d.		s. d.
FIRST STANDARD	0 6	FOURTH STANDARD	1 2
SECOND „	0 10	FIFTH „	1 6
THIRD „	1 0	SIXTH „	1 6

LESSONS FROM THE BIBLE. Part I. Old Testament. 1s.

LESSONS FROM THE BIBLE. Part II. New Testament, to which is added THE GEOGRAPHY OF THE BIBLE, for very young Children. By Rev. C. THORNTON FORSTER. 1s. 2d. *** Or the Two Parts in One Volume. 2s.

FRENCH.

24. **French Grammar.** With Complete and Concise Rules on the Genders of French Nouns. By G. L. STRAUSS, Ph.D. 1s. 6d.
25. **French-English Dictionary.** Comprising a large number of New Terms used in Engineering, Mining, &c. By ALFRED ELWES. 1s. 6d.
26. **English-French Dictionary.** By ALFRED ELWES. 2s.
25,26. **French Dictionary** (as above). Complete, in One Vol., 3s.; cloth boards, 3s. 6d. *** Or with the GRAMMAR, cloth boards, 4s. 6d.
47. **French and English Phrase Book:** containing Introductory Lessons, with Translations, several Vocabularies of Words, a Collection of suitable Phrases, and Easy Familiar Dialogues. 1s. 6d.

GERMAN.

39. **German Grammar.** Adapted for English Students, from Heyse's Theoretical and Practical Grammar, by Dr. G. L. STRAUSS. 1s. 6d.
40. **German Reader:** A Series of Extracts, carefully culled from the most approved Authors of Germany; with Notes, Philological and Explanatory. By G. L. STRAUSS, Ph.D. 1s.
41-43. **German Triglot Dictionary.** By N. E. S. A. HAMILTON. In Three Parts. Part I. German-French-English. Part II. English-German-French. Part III. French-German-English. 3s., or cloth boards, 4s.
41-43 & 39. **German Triglot Dictionary** (as above), together with German Grammar (No. 39), in One Volume, cloth boards, 5s.

ITALIAN.

27. **Italian Grammar,** arranged in Twenty Lessons, with a Course of Exercises. By ALFRED ELWES. 1s. 6d.
28. **Italian Triglot Dictionary,** wherein the Genders of all the Italian and French Nouns are carefully noted down. By ALFRED ELWES. Vol. 1. Italian-English-French. 2s. 6d.
30. **Italian Triglot Dictionary.** By A. ELWES. Vol. 2. English-French-Italian. 2s. 6d.
32. **Italian Triglot Dictionary.** By ALFRED ELWES. Vol. 3. French-Italian-English. 2s. 6d.
28,30, 32. **Italian Triglot Dictionary** (as above). In One Vol., 7s. 6d. Cloth boards.

SPANISH AND PORTUGUESE.

34. **Spanish Grammar,** in a Simple and Practical Form. With a Course of Exercises. By ALFRED ELWES. 1s. 6d.
35. **Spanish-English and English-Spanish Dictionary.** Including a large number of Technical Terms used in Mining, Engineering, &c., with the proper Accents and the Gender of every Noun. By ALFRED ELWES. 4s.; cloth boards, 5s. *** Or with the GRAMMAR, cloth boards, 6s.
55. **Portuguese Grammar,** in a Simple and Practical Form. With a Course of Exercises. By ALFRED ELWES. 1s. 6d.
56. **Portuguese-English and English-Portuguese Dictionary.** Including a large number of Technical Terms used in Mining, Engineering, &c., with the proper Accents and the Gender of every Noun. By ALFRED ELWES. 5s.; cloth boards, 6s. *** Or with the GRAMMAR, cloth boards, 7s.

HEBREW.

46*. **Hebrew Grammar.** By Dr. BRESSLAU. 1s. 6d.
44. **Hebrew and English Dictionary,** Biblical and Rabbinical; containing the Hebrew and Chaldee Roots of the Old Testament Post-Rabbinical Writings. By Dr. BRESSLAU. 6s.
46. **English and Hebrew Dictionary.** By Dr. BRESSLAU. 3s.
44,46. 46*. **Hebrew Dictionary** (as above), in Two Vols., complete, with the GRAMMAR, cloth boards, 12s.

LATIN.

19. **Latin Grammar.** Containing the Inflections and Elementary Principles of Translation and Construction. By the Rev. THOMAS GOODWIN, M.A., Head Master of the Greenwich Proprietary School. 1s. 6d.

20. **Latin-English Dictionary.** By the Rev. THOMAS GOODWIN, M.A. 2s.

22. **English-Latin Dictionary;** together with an Appendix of French and Italian Words which have their origin from the Latin. By the Rev. THOMAS GOODWIN, M.A. 1s. 6d.

20,22. **Latin Dictionary** (as above). Complete in One Vol., 3s. 6d. cloth boards, 4s. 6d. *.* Or with the GRAMMAR, cloth boards, 5s. 6d.

LATIN CLASSICS. With Explanatory Notes in English.

1. **Latin Delectus.** Containing Extracts from Classical Authors, with Genealogical Vocabularies and Explanatory Notes, by H. YOUNG. 1s. 6d.

2. **Cæsaris** Commentarii de Bello Gallico. Notes, and a Geographical Register for the Use of Schools, by H. YOUNG. 2s.

3. **Cornelius Nepos.** With Notes. By H. YOUNG. 1s.

4. **Virgilii** Maronis Bucolica et Georgica. With Notes on the Bucolics by W. RUSHTON, M.A., and on the Georgics by H. YOUNG. 1s. 6d.

5. **Virgilii** Maronis Æneis. With Notes, Critical and Explanatory, by H. YOUNG. New Edition, revised and improved With copious Additional Notes by Rev. T. H. L. LEARY, D.C.L., formerly Scholar of Brasenose College, Oxford. 3s.

5* ——— Part 1. Books i.—vi., 1s. 6d.

5** ——— Part 2. Books vii.—xii., 2s.

6. **Horace;** Odes, Epode, and Carmen Sæculare. Notes by H. YOUNG. 1s. 6d.

7. **Horace;** Satires, Epistles, and Ars Poetica. Notes by W. BROWNRIGG SMITH, M.A., F.R.G.S. 1s. 6d.

8. **Sallustii** Crispi Catalina et Bellum Jugurthinum. Notes, Critical and Explanatory, by W. M. DONNE, B.A., Trin. Coll., Cam. 1s. 6d.

9. **Terentii** Andria et Heautontimorumenos. With Notes, Critical and Explanatory, by the Rev. JAMES DAVIES, M.A. 1s. 6d.

10. **Terentii** Adelphi, Hecyra, Phormio. Edited, with Notes, Critical and Explanatory, by the Rev. JAMES DAVIES, M.A. 2s.

11. **Terentii** Eunuchus, Comœdia. Notes, by Rev. J. DAVIES, M.A. 1s. 6d.

12. **Ciceronis** Oratio pro Sexto Roscio Amerino. Edited, with an Introduction, Analysis, and Notes, Explanatory and Critical, by the Rev. JAMES DAVIES, M.A. 1s. 6d.

13. **Ciceronis** Orationes in Catilinam, Verrem, et pro Archia. With Introduction, Analysis, and Notes, Explanatory and Critical, by Rev. T. H. L. LEARY, D.C.L. formerly Scholar of Brasenose College, Oxford. 1s. 6d.

14. **Ciceronis** Cato Major, Lælius, Brutus, sive de Senectute, de Amicitia, de Claris Oratoribus Dialogi. With Notes by W. BROWNRIGG SMITH, M.A., F.R.G.S. 2s.

16. **Livy:** History of Rome. Notes by H. YOUNG and W. B. SMITH, M.A. Part 1. Books i., ii., 1s. 6d.

16*. ——— Part 2. Books iii., iv., v., 1s. 6d.

17. ——— Part 3. Books xxi., xxii., 1s. 6d.

19. **Latin Verse Selections,** from Catullus, Tibullus, Propertius, and Ovid. Notes by W. B. DONNE, M.A., Trinity College, Cambridge. 2s.

20. **Latin Prose Selections,** from Varro, Columella, Vitruvius, Seneca, Quintilian, Florus, Velleius Paterculus, Valerius Maximus Suetonius, Apuleius, &c. Notes by W. B. DONNE, M.A. 2s.

21. **Juvenalis** Satiræ. With Prolegomena and Notes by T. H. S. ESCOTT, B.A., Lecturer on Logic at King's College, London. 2s.

GREEK.

14. **Greek Grammar**, in accordance with the Principles and Philological Researches of the most eminent Scholars of our own day. By HANS CLAUDE HAMILTON. 1s. 6d.

15,17. **Greek Lexicon.** Containing all the Words in General Use, with their Significations, Inflections, and Doubtful Quantities. By HENRY R. HAMILTON. Vol. 1. Greek-English, 2s. 6d.; Vol. 2. English-Greek, 2s. Or the Two Vols. in One, 4s. 6d.: cloth boards, 5s.

14,15,17. **Greek Lexicon** (as above). Complete, with the GRAMMAR, in One Vol., cloth boards, 6s.

GREEK CLASSICS. With Explanatory Notes in English.

1. **Greek Delectus.** Containing Extracts from Classical Authors, with Genealogical Vocabularies and Explanatory Notes, by H. YOUNG. New Edition, with an improved and enlarged Supplementary Vocabulary, by JOHN HUTCHISON, M.A., of the High School, Glasgow. 1s. 6d.

2, 3. **Xenophon's Anabasis**; or, The Retreat of the Ten Thousand. Notes and a Geographical Register, by H. YOUNG. Part 1. Books i. to iii., 1s. Part 2. Books iv. to vii., 1s.

4. **Lucian's Select Dialogues.** The Text carefully revised, with Grammatical and Explanatory Notes, by H. YOUNG. 1s. 6d.

5-12. **Homer, The Works of.** According to the Text of BAEUMLEIN. With Notes, Critical and Explanatory, drawn from the best and latest Authorities, with Preliminary Observations and Appendices, by T. H. L. LEARY, M.A., D.C.L.

THE ILIAD:	Part 1. Books i. to vi., 1s. 6d.	Part 3. Books xiii. to xviii., 1s. 6d.
	Part 2. Books vii. to xii., 1s. 6d.	Part 4. Books xix. to xxiv., 1s. 6d.
THE ODYSSEY:	Part 1. Books i. to vi., 1s. 6d.	Part 3. Books xiii. to xviii., 1s. 6d.
	Part 2. Books vii. to xii., 1s. 6d.	Part 4. Books xix. to xxiv., and Hymns, 2s.

13. **Plato's Dialogues:** The Apology of Socrates, the Crito, and the Phædo. From the Text of C. F. HERMANN. Edited with Notes, Critical and Explanatory, by the Rev. JAMES DAVIES, M.A. 2s.

14-17. **Herodotus,** The History of, chiefly after the Text of GAISFORD. With Preliminary Observations and Appendices, and Notes, Critical and Explanatory, by T. H. L. LEARY, M.A., D.C.L.
Part 1. Books i., ii. (The Clio and Euterpe), 2s.
Part 2. Books iii., iv. (The Thalia and Melpomene), 2s.
Part 3. Books v.-vii. (The Terpsichore, Erato, and Polymnia), 2s.
Part 4. Books viii., ix. (The Urania and Calliope) and Index, 1s. 6d.

18. **Sophocles:** Œdipus Tyrannus. Notes by H. YOUNG. 1s.

20. **Sophocles:** Antigone. From the Text of DINDORF. Notes, Critical and Explanatory, by the Rev. JOHN MILNER, B.A. 2s.

23. **Euripides:** Hecuba and Medea. Chiefly from the Text of DINDORF. With Notes, Critical and Explanatory, by W. BROWNRIGG SMITH, M.A., F.R.G.S. 1s. 6d.

26. **Euripides:** Alcestis. Chiefly from the Text of DINDORF. With Notes, Critical and Explanatory, by JOHN MILNER, B.A. 1s. 6d.

30. **Æschylus:** Prometheus Vinctus: The Prometheus Bound. From the Text of DINDORF. Edited, with English Notes, Critical and Explanatory, by the Rev. JAMES DAVIES, M.A. 1s.

32. **Æschylus:** Septem Contra Thebes: The Seven against Thebes. From the Text of DINDORF. Edited, with English Notes, Critical and Explanatory, by the Rev. JAMES DAVIES, M.A. 1s.

40. **Aristophanes:** Acharnians. Chiefly from the Text of C. H. WEISE. With Notes, by C. S. T. TOWNSHEND, M.A. 1s. 6d.

41. **Thucydides:** History of the Peloponnesian War. Notes by H. YOUNG. Book 1. 1s. 6d.

42. **Xenophon's Panegyric on Agesilaus.** Notes and Introduction by LL. F. W. JEWITT. 1s. 6d.

43. **Demosthenes.** The Oration on the Crown and the Philippics. With English Notes. By Rev. T. H. L. LEARY, D.C.L., formerly Scholar of Brasenose College, Oxford. 1s. 6d.

7, STATIONERS' HALL COURT, LONDON, E.C.
January, 1888.

A

CATALOGUE OF BOOKS

INCLUDING MANY NEW AND STANDARD WORKS IN

ENGINEERING, MECHANICS, ARCHITECTURE,

NATURAL AND APPLIED SCIENCE,

INDUSTRIAL ARTS, TRADE AND COMMERCE, AGRICULTURE,

GARDENING, LAND MANAGEMENT, LAW, &c.

PUBLISHED BY

CROSBY LOCKWOOD & SON.

MECHANICS, MECHANICAL ENGINEERING, etc.

New Manual for Practical Engineers.

THE PRACTICAL ENGINEER'S HAND-BOOK. Comprising a Treatise on Modern Engines and Boilers, Marine, Locomotive and Stationary. And containing a large collection of Rules and Practical Data relating to recent Practice in Designing and Constructing all kinds of Engines, Boilers, and other Engineering work. The whole constituting a comprehensive Key to the Board of Trade and other Examinations for Certificates of Competency in Modern Mechanical Engineering. By WALTER S. HUTTON, Civil and Mechanical Engineer, Author of "The Works' Manager's Hand-book for Engineers," &c. With upwards of 370 Illustrations. Second Edition, Revised with Additions. Medium 8vo, nearly 500 pp., price 18s. Strongly bound. [*Just published.*

☞ *This work is designed as a companion to the Author's* "WORKS' MANAGER'S HAND-BOOK." *It possesses many new and original features, and contains, like its predecessor, a quantity of matter not originally intended for publication, but collected by the author for his own use in the construction of a great variety of modern engineering work.*

The information is given in a condensed and concise form, and is illustrated by upwards of 370 *Woodcuts; and comprises a quantity of tabulated matter of great value to all engaged in designing, constructing, or estimating for* ENGINES, BOILERS *and* OTHER ENGINEERING WORK.

*** OPINIONS OF THE PRESS.

"We have kept it at hand for several weeks, referring to it as occasion arose, and we have not on a single occasion consulted its pages without finding the information of which we were in quest." —*Athenæum.*

"A thoroughly good practical handbook, which no engineer can go through without learning something that will be of service to him."—*Marine Engineer.*

"An excellent book of reference for engineers, and a valuable text-book for students of engineering."—*Scotsman.*

"This valuable manual embodies the results and experience of the leading authorities on mechanical engineering."—*Building News.*

"The author has collected together a surprising quantity of rules and practical data, and has shown much judgment in the selections he has made. . . . There is no doubt that this book is one of the most useful of its kind published, and will be a very popular compendium."—*Engineer.*

"A mass of information, set down in simple language, and in such a form that it can be easily referred to at any time. The matter is uniformly good and well chosen, and is greatly elucidated by the illustrations. The book will find its way on to most engineers' shelves, where it will rank as one of the most useful books of reference."—*Practical Engineer.*

"Full of useful information, and should be found on the office shelf of all practical engineers." —*English Mechanic.*

Handbook for Works' Managers.

THE WORKS' MANAGER'S HANDBOOK OF MODERN RULES, TABLES, AND DATA. For Engineers, Millwrights, and Boiler Makers; Tool Makers, Machinists, and Metal Workers; Iron and Brass Founders, &c. By W. S. HUTTON, Civil and Mechanical Engineer, Author of "The Practical Engineer's Handbook." Third Edition, carefully Revised, with Additions. In One handsome Vol., medium 8vo, price 15s. strongly bound.

☞ *The Author having compiled Rules and Data for his own use in a great variety of modern engineering work, and having found his notes extremely useful, decided to publish them—revised to date—believing that a practical work, suited to the* DAILY REQUIREMENTS OF MODERN ENGINEERS, *would be favourably received.*

In the Third Edition, the following among other additions have been made, viz.: Rules for the Proportions of Riveted Joints in Soft Steel Plates, the Results of Experiments by PROFESSOR KENNEDY *for the Institution of Mechanical Engineers—Rules for the Proportions of Turbines—Rules for the Strength of Hollow Shafts of Whitworth's Compressed Steel, &c.*

*** OPINIONS OF THE PRESS.

"The author treats every subject from the point of view of one who has collected workshop notes for application in workshop practice, rather than from the theoretical or literary aspect. The volume contains a great deal of that kind of information which is gained only by practical experience, and is seldom written in books."—*Engineer.*

"The volume is an exceedingly useful one, brimful with engineers' notes, memoranda, and rules, and well worthy of being on every mechanical engineer's bookshelf."—*Mechanical World.*

"A formidable mass of facts and figures, readily accessible through an elaborate index . . . . Such a volume will be found absolutely necessary as a book of reference in all sorts of 'works' connected with the metal trades."—*Ryland's Iron Trades Circular.*

"Brimful of useful information, stated in a concise form, Mr. Hutton's books have met a pressing want among engineers. The book must prove extremely useful to every practical man possessing a copy."—*Practical Engineer.*

The Modernised "Templeton."

THE PRACTICAL MECHANIC'S WORKSHOP COMPANION. Comprising a great variety of the most useful Rules and Formulæ in Mechanical Science, with numerous Tables of Practical Data and Calculated Results for Facilitating Mechanical Operations. By WILLIAM TEMPLETON, Author of "The Engineer's Practical Assistant," &c. &c. Fifteenth Edition, Revised, Modernised, and considerably Enlarged by WALTER S. HUTTON, C.E., Author of "The Works' Manager's Handbook," "The Practical Engineer's Handbook," &c. Fcap. 8vo, nearly 500 pp., with Eight Plates and upwards of 250 Illustrative Diagrams, 6s., strongly bound for workshop or pocket wear and tear.

☞ TEMPLETON'S "MECHANIC'S WORKSHOP COMPANION" *has been for more than a quarter of a century deservedly popular, and, as a recognised Text-Book and well-worn and thumb-marked* vade mecum *of several generations of intelligent and aspiring workmen, it has had the reputation of having been the means of raising many of them in their position in life.*

In consequence of the lapse of time since the Author's death, and the great advances in Mechanical Science, the Publishers have thought it advisable to have it entirely Reconstructed and Modernised; and in its present greatly Enlarged and Improved form, they are sure that it will commend itself to the English workmen of the present day all the world over, and become, like its predecessors, their indispensable friend and referee.

A smaller type having been adopted, and the page increased in size, while the number of pages has advanced from about 330 *to nearly* 500, *the book practically contains double the amount of matter that was comprised in the original work.*

*** OPINIONS OF THE PRESS.

"In its modernised form Hutton's 'Templeton' should have a wide sale, for it contains much valuable information which the mechanic will often find of use, and not a few tables and notes which he might look for in vain in other works. This modernised edition will be appreciated by all who have learned to value the original editions of 'Templeton.'"—*English Mechanic.*

"It has met with great success in the engineering workshop, as we can testify; and there are a great many men who, in a great measure, owe their rise in life to this little book."—*Building News.*

"This familiar text-book—well known to all mechanics and engineers—is of essential service to the every-day requirements of engineers, millwrights and the various trades connected with engineering and building. The new modernised edition is worth its weight in gold."—*Building News* (Second Notice.)

"The publishers wisely entrusted the task of revision of this popular, valuable and useful book to Mr. Hutton, than whom a more competent man they could not have found."—*Iron.*

Stone-working Machinery.

STONE-WORKING MACHINERY, and the Rapid and Economical Conversion of Stone. With Hints on the Arrangement and Management of Stone Works. By M. POWIS BALE, M.I.M.E., A.M.I.C.E. With numerous Illustrations. Large crown 8vo, 9s. cloth.

"The book should be in the hands of every mason or student of stone-work."—*Colliery Guardian.*

"It is in every sense of the word a standard work upon a subject which the author is fully competent to deal exhaustively with."—*Builder's Weekly Reporter.*

"A capital handbook for all who manipulate stone for building or ornamental purposes."—*Machinery Market.*

Turning.

LATHE-WORK: A Practical Treatise on the Tools, Appliances, and Processes employed in the Art of Turning. By PAUL N. HASLUCK. Third Edition, Revised and Enlarged. Crown 8vo, 5s. cloth.

"Written by a man who knows, not only how work ought to be done, but who also knows how to do it, and how to convey his knowledge to others. To all turners this book would be valuable.—*Engineering.*

"We can safely recommend the work to young engineers. To the amateur it will simply be invaluable. To the student it will convey a great deal of useful information."—*Engineer.*

"A compact, succinct, and handy guide to lathe-work did not exist in our language unt Mr. Hasluck, by the publication of this treatise, gave the turner a true *vade-mecum.*"—*House Decorator.*

Screw-Cutting.

SCREW THREADS: And Methods of Producing Them. With Numerous Tables, and complete directions for using Screw-Cutting Lathes. By PAUL N. HASLUCK, Author of "Lathe-Work," "The Metal Turner's Handybook," &c. Waistcoat-pocket size, price 1s. [*Just published.*

"Full of useful information, hints and practical criticism. Taps, dies and sc ewing-tools generally are illustrated and their action described"—*Mechanical World*

"It is a complete compendium of all the details of the screw-cutting lathe; in fact, a *multum in parvo* on all the subjects it treats upon."—*Carpenter and Builder.*

Engineer's and Machinist's Assistant.

THE ENGINEER'S, MILLWRIGHT'S, and MACHINIST'S PRACTICAL ASSISTANT. A collection of Useful Tables, Rules and Data. By WILLIAM TEMPLETON. Seventh Edition, with Additions. 18mo, 2s. 6d. cloth.

"Templeton's handbook occupies a foremost place among books of this kind. A more suitable present to an apprentice to any of the mechanical trades could not possibly be made."—*Building News.*

"A deservedly appreciated work, which should be in the 'drawer' of every mechanic."—*English Mechanic.*

Iron and Steel.

"IRON AND STEEL": A Work for the Forge, Foundry, Factory, and Office. Containing ready, useful, and trustworthy Information for Ironmasters and their Stock-takers; Managers of Bar, Rail, Plate, and Sheet Rolling Mills; Iron and Metal Founders; Iron Ship and Bridge Builders; Mechanical, Mining, and Consulting Engineers; Architects, Contractors, Builders, and Professional Draughtsmen. By CHARLES HOARE, Author of "The Slide Rule," &c. Eighth Edition, Revised throughout and considerably Enlarged. With folding Scales of "Foreign Measures compared with the English Foot," and "Fixed Scales of Squares, Cubes, and Roots, Areas, Decimal Equivalents," &c. Oblong 32mo, leather, elastic band, 6s.

"For comprehensiveness the book has not its equal."—*Iron.*

"One of the best of the pocket books, and a useful companion in other branches of work than iron and steel."—*English Mechanic.*

"We cordially recommend this book to those engaged in considering the details of all kinds of iron and steel works."—*Naval Science.*

High-Pressure Steam Engines.

THE HIGH-PRESSURE STEAM-ENGINE: An Exposition of its Comparative Merits and an Essay towards an Improved System of Construction. By Dr. ERNST ALBAN. Translated from the German, with Notes, by Dr. POLE, M. Inst. C.E., &c. With 28 Plates. 8vo, 16s. 6d. cloth.

"Goes thoroughly into the examination of the high-pressure engine, the boiler, and its appendages, and deserves a place in every scientific library."—*Steam Shipping Chronicle.*

Engineering Construction.

PATTERN-MAKING: A Practical Treatise, embracing the Main Types of Engineering Construction, and including Gearing, both Hand and Machine made, Engine Work, Sheaves and Pulleys, Pipes and Columns, Screws, Machine Parts, Pumps and Cocks, the Moulding of Patterns in Loam and Greensand, &c., together with the methods of Estimating the weight of Castings; to which is added an Appendix of Tables for Workshop Reference. By a FOREMAN PATTERN MAKER. With upwards of Three Hundred and Seventy Illustrations. Crown 8vo, 7s. 6d. cloth.

"A well-written technical guide, evidently written by a man who understands and has practised what he has written about. We cordially recommend it to engineering students, young journeymen, and others desirous of being initiated into the mysteries of pattern-making."—*Builder.*

"Likely to prove a welcome guide to many workmen, especially to draughtsmen who have lacked a training in the shops, pupils pursuing their practical studies in our factories, and to employers and managers in engineering works."—*Hardware Trade Journal.*

"More than 370 illustrations help to explain the text, which is, however, always clear and explicit, thus rendering the work an excellent *vade mecum* for the apprentice who desires to become master of his trade."—*English Mechanic.*

Dictionary of Mechanical Engineering Terms.

LOCKWOOD'S DICTIONARY OF TERMS USED IN THE PRACTICE OF MECHANICAL ENGINEERING, embracing those current in the Drawing Office, Pattern Shop, Foundry, Fitting, Turning, Smith's and Boiler Shops, &c. &c. Comprising upwards of 6,000 Definitions. Edited by A FOREMAN PATTERN-MAKER, Author of "Pattern Making." Crown 8vo, 7s. 6d. cloth. [*Just published.*

"Just the sort of handy dictionary required by the various trades engaged in mechanical en-

...cely t...

"This admirable dictionary, although primarily intended for the use of draughtsmen and other technical craftsmen, is of much larger value as a book of reference, and will find a ready welcome in many libraries."—*Glasgow Herald.*

Smith's Tables for Mechanics, etc.

TABLES, MEMORANDA, AND CALCULATED RESULTS, FOR MECHANICS, ENGINEERS, ARCHITECTS, BUILDERS, etc. Selected and Arranged by FRANCIS SMITH. Fourth Edition, Revised and Enlarged, 250 pp., waistcoat-pocket size, 1s. 6d. limp leather. [*Just published.*

"It would, perhaps, be as difficult to make a small pocket-book selection of notes and formulæ to suit ALL engineers as it would be to make a universal medicine; but Mr. Smith's waistcoat-pocket collection may be looked upon as a successful attempt."—*Engineer.*

"The best example we have ever seen of 250 pages of useful matter packed into the dimensions of a card-case."—*Building News.*

"A veritable pocket treasury of knowledge."—*Iron.*

Steam Boilers.

A TREATISE ON STEAM BOILERS: Their Strength, Construction, and Economical Working. By ROBERT WILSON, C.E. Fifth Edition. 12mo, 6s. cloth.

"The best treatise that has ever been published on steam boilers."—*Engineer.*

"The author shows himself perfect master of his subject, and we heartily recommend all employing steam power to possess themselves of the work."—*Ryland's Iron Trade Circular.*

Boiler Chimneys.

BOILER AND FACTORY CHIMNEYS; Their Draught-Power and Stability. With a Chapter on *Lightning Conductors.* By ROBERT WILSON, A.I.C.E., Author of "A Treatise on Steam Boilers," &c. Second Edition. Crown 8vo, 3s. 6d. cloth. [*Just published.*

Boiler Making.

THE BOILER-MAKER'S READY RECKONER. With Examples of Practical Geometry and Templating, for the Use of Platers, Smiths and Riveters. By JOHN COURTNEY, Edited by D. K. CLARK, M.I.C.E. Second Edition, Revised, with Additions, 12mo, 5s. half-bound.

"A most useful work. . . . . No workman or apprentice should be without this book."—*Iron Trade Circular.*

"A reliable guide to the working boiler-maker."—*Iron.*

"Boiler-makers will readily recognise the value of this volume. . . . The tables are clearly printed, and so arranged that they can be referred to with the greatest facility, so that cannot be doubted that they will be generally appreciated and much used."—*Mining Journal.*

Steam Engine.

TEXT-BOOK ON THE STEAM ENGINE. With a Supplement on Gas Engines. By T. M. GOODEVE, M.A., Barrister-at-Law, Author of "The Elements of Mechanism," &c. Ninth Edition. With numerous Illustrations. Crown 8vo, 6s. cloth.

"Professor Goodeve has given us a treatise on the steam engine which will bear comparison with anything written by Huxley or Maxwell, and we can award it no higher praise."—*Engineer.*

"Professor Goodeve's book is ably and clearly written. It is a sound work."—*Athenæum.*

"Mr. Goodeve's text-book is a work of which every young engineer should possess himself." —*Mining Journal.*

"Essentially practical in its aims. The manner of exposition leaves nothing to be desired."—*Scotsman.*

"A valuable *vade mecum* for the student of engineering, and should be in the possession of every scientific reader."—*Colliery Guardian.*

Gas Engines.

ON GAS-ENGINES. Being a Reprint, with some Additions, of the Supplement to the *Text-book on the Steam Engine*, by T. M. GOODEVE, M.A. Crown 8vo, 2s. 6d. cloth. [*Just published.*

"Like all Mr Goodeve's writings, the present is no exception in point of general excellence. It is a valuable little volume."—*Mechanical World.*

"This little book will be useful to those who desire to understand how the gas-engine works. —*English Mechanic.*

Steam.

THE SAFE USE OF STEAM. Containing Rules for Unprofessional Steam-users. By an ENGINEER. Fifth Edition. Sewed, 6d.

"If steam-users would but learn this little book by heart, boiler explosions would become sensations by their rarity."—*English Mechanic.*

Coal and Speed Tables.

A POCKET BOOK OF COAL AND SPEED TABLES, for Engineers and Steam-users. By NELSON FOLEY, Author of "Boiler Construction." Pocket-size, 3s. 6d. cloth; 4s. leather.

"This is a very useful book, containing very useful tables. The results given are well chosen, and the volume contains evidence that the author really understands his subject. We can recommend the work with pleasure."—*Mechanical World.*

"These tables are designed to meet the requirements of every-day use; they are of sufficient scope for most practical purposes, and may be commended to engineers and users of steam."—*Iron.*

"This pocket-book well merits the attention of the practical engineer. Mr. Foley has compiled a very useful set of tables, the information contained in which is frequently required by engineers, coal consumers and users of steam."—*Iron and Coal Trades Review.*

Fire Engineering.

FIRES, FIRE-ENGINES, AND FIRE-BRIGADES. With a History of Fire-Engines, their Construction, Use, and Management; Remarks on Fire-Proof Buildings, and the Preservation of Life from Fire; Statistics of the Fire Appliances in English Towns; Foreign Fire Systems; Hints on Fire Brigades, &c. &c. By CHARLES F. T. YOUNG, C.E. With numerous Illustrations, 544 pp., demy 8vo, £1 4s. cloth.

"To such of our readers as are interested in the subject of fires and fire apparatus, we can most heartily commend this book. It is really the only English work we now have upon the subject."—*Engineering.*

"It displays much evidence of careful research; and Mr. Young has put his facts neatly together. It is evident enough that his acquaintance with the practical details of the construction of steam fire engines, old and new, and the conditions with which it is necessary they should comply, is accurate and full."—*Engineer.*

Gas Lighting.

COMMON SENSE FOR GAS-USERS: A Catechism of Gas-Lighting for Householders, Gasfitters, Millowners, Architects, Engineers, etc. By ROBERT WILSON, C.E., Author of "A Treatise on Steam Boilers." Second Edition, with Folding Plates and Wood Engravings. Crown 8vo, price 1s. in wrapper.

"All gas-users will decidedly benefit, both in pocket and comfort, if they will avail themselves of Mr. Wilson's counsels."—*Engineering.*

THE POPULAR WORKS OF MICHAEL REYNOLDS

("THE ENGINE DRIVER'S FRIEND").

Locomotive-Engine Driving.

LOCOMOTIVE-ENGINE DRIVING: A Practical Manual for Engineers in charge of Locomotive Engines. By MICHAEL REYNOLDS, Member of the Society of Engineers, formerly Locomotive Inspector L. B. and S. C. R. Eighth Edition. Including a KEY TO THE LOCOMOTIVE ENGINE. With Illustrations and Portrait of Author. Crown 8vo, 4s. 6d. cloth.

"Mr. Reynolds has supplied a want, and has supplied it well. We can confidently recommend the book, not only to the practical driver, but to everyone who takes an interest in the performance of locomotive engines."—*The Engineer.*

"Mr. Reynolds has opened a new chapter in the literature of the day. This admirable practical treatise, of the practical utility of which we have to speak in terms of warm commendation."—*Athenæum.*

"Evidently the work of one who knows his subject thoroughly."—*Railway Service Gazette.*

"Were the cautions and rules given in the book to become part of the every-day working of our engine-drivers, we might have fewer distressing accidents to deplore."—*Scotsman.*

Stationary Engine Driving.

STATIONARY ENGINE DRIVING: A Practical Manual for Engineers in charge of Stationary Engines. By MICHAEL REYNOLDS. Third Edition, Enlarged. With Plates and Woodcuts. Crown 8vo, 4s. 6d. cloth.

"The author is thoroughly acquainted with his subjects, and his advice on the various points treated is clear and practical. . . He has produced a manual which is an exceedingly useful one for the class for whom it is specially intended."—*Engineering.*

"Our author leaves no stone unturned. He is determined that his readers shall not only know something about the stationary engine, but all about it."—*Engineer.*

"An engineman who has mastered the contents of Mr. Reynolds's book will require but little actual experience with boilers and engines before he can be trusted to look after them."—*English Mechanic*

The Engineer, Fireman, and Engine-Boy.

THE MODEL LOCOMOTIVE ENGINEER, FIREMAN, and ENGINE-BOY. Comprising a Historical Notice of the Pioneer Locomotive Engines and their Inventors. By MICHAEL REYNOLDS. With numerous Illustrations and a fine Portrait of George Stephenson. Crown 8vo, 4s. 6d. cloth.

"From the technical knowledge of the author it will appeal to the railway man of to-day more forcibly than anything written by Dr. Smiles. . . . The volume contains information of a technical kind, and facts that every driver should be familiar with."—*English Mechanic.*

"We should be glad to see this book in the possession of everyone in the kingdom who has ever laid, or is to lay, hands on a locomotive engine."—*Iron.*

Continuous Railway Brakes.

CONTINUOUS RAILWAY BRAKES: A Practical Treatise on the several Systems in Use in the United Kingdom; their Construction and Performance. With copious Illustrations and numerous Tables. By MICHAEL REYNOLDS. Large crown 8vo, 9s. cloth.

"A popular explanation of the different brakes. It will be of great assistance in forming public opinion, and will be studied with benefit by those who take an interest in the brake."—*English Mechanic.*

"Written with sufficient technical detail to enable the principle and relative connection of the various parts of each particular brake to be readily grasped."—*Mechanical World.*

Engine-Driving Life.

ENGINE-DRIVING LIFE; or, Stirring Adventures and Incidents in the Lives of Locomotive-Engine Drivers. By MICHAEL REYNOLDS. Ninth Thousand. Crown 8vo. 2s. cloth.

"From first to last is perfectly fascinating. Wilkie Collins's most thrilling conceptions are thrown into the shade by true incidents, endless in their variety, related in every page."—*North British Mail.*

"Anyone who wishes to get a real insight into railway life cannot do better than read 'Engine-Driving Life' for himself; and if he once take it up he will find that the author's enthusiasm and real love of the engine-driving profession will carry him on till he has read every page."—*Saturday Review.*

Pocket Companion for Enginemen.

THE ENGINEMAN'S POCKET COMPANION AND PRACTICAL EDUCATOR FOR ENGINEMEN, BOILER ATTENDANTS, AND MECHANICS. By MICHAEL REYNOLDS. With Forty-five Illustrations and numerous Diagrams. Second Edition, Revised. Royal 18mo, 3s. 6d., strongly bound for pocket wear. [*Just published.*

"This admirable work is well suited to accomplish its object, being the honest workmanship of a competent engineer."—*Glasgow Herald.*

"A most meritorious work, giving in a succinct and practical form all the information an engine-minder desirous of mastering the scientific principles of his daily calling would require."—*Miller.*

"A boon to those who are striving to become efficient mechanics."—*Daily Chronicle.*

MR. HUMBER'S GREAT WORK ON MODERN ENGINEERING.

Complete in Four Volumes, imperial 4to, price £12 12s., half-morocco. Each Volume sold separately as follows:—

A RECORD OF THE PROGRESS OF MODERN ENGINEERING. FIRST SERIES. Comprising Civil, Mechanical, Marine, Hydraulic, Railway, Bridge, and other Engineering Works, &c. By WILLIAM HUMBER, A-M. Inst. C.E., &c. Imp. 4to, with 36 Double Plates, drawn to a large scale, Photographic Portrait of John Hawkshaw, C.E., F.R.S., &c., and copious descriptive Letterpress, Specifications, &c., £3 3s. half-morocco.

List of the Plates and Diagrams.

Victoria Station and Roof, L. B. & S. C. R. (8 plates); Southport Pier (2 plates); Victoria Station and Roof, L. C. & D and G. W. R. (6 plates); Roof of Cremorne Music Hall, Bridge over G. N. Railway; Roof of Station, Dutch Rhenish Rail (2 plates); Bridge over the Thames, West London Extension Railway (5 plates); Armour Plates: Suspension Bridge, Thames (4 plates), The Allen Engine; Suspension Bridge, Avon (3 plates); Underground Railway (3 plates).

"Handsomely lithographed and printed. It will find favour with many who desire to preserve in a permanent form copies of the plans and specifications prepared for the guidance of the contractors for many important engineering works."—*Engineer.*

HUMBER'S RECORD OF MODERN ENGINEERING. SECOND SERIES. Imp. 4to, with 36 Double Plates, Photographic Portrait of Robert Stephenson, C.E., M.P., F.R.S., &c., and copious descriptive Letterpress, Specifications, &c., £3 3s. half-morocco.

List of the Plates and Diagrams.

Birkenhead Docks, Low Water Basin (15 plates); Charing Cross Station Roof, C. C. Railway (3 plates); Digswell Viaduct, Great Northern Railway; Robbery Wood Viaduct, Great Northern Railway; Iron Permanent Way, Clydach Viaduct, Merthyr, Tredegar, and Abergavenny Railway; Ebbw Viaduct, Merthyr, Tredegar, and Abergavenny Railway; College Wood Viaduct, Cornwall Railway; Dublin Winter Palace Roof (3 plates); Bridge over the Thames, L. C. & D. Railway (6 plates); Albert Harbour, Greenock (4 plates)

"Mr. Humber has done the profession good and true service, by the fine collection of examples he has here brought before the profession and the public"—*Practical Mechanic's Journal.*

HUMBER'S RECORD OF MODERN ENGINEERING. THIRD SERIES. Imp. 4to, with 40 Double Plates, Photographic Portrait of J. R. M'Clean, late Pres. Inst. C.E., and copious descriptive Letterpress, Specifications, &c., £3 3s. half-morocco.

List of the Plates and Diagrams.

MAIN DRAINAGE, METROPOLIS.—*North Side.*—Map showing Interception of Sewers; Middle Level Sewer (2 plates); Outfall Sewer, Bridge over River Lea (3 plates), Outfall Sewer, Bridge over Marsh Lane, North Woolwich Railway, and Bow and Barking Railway Junction; Outfall Sewer, Bridge over Bow and Barking Railway (3 plates); Outfall Sewer, Bridge over East London Waterworks' Feeder (2 plates), Outfall Sewer, Reservoir (2 plates); Outfall Sewer, Tumbling Bay and Outlet; Outfall Sewer, Penstocks. *South Side.*—Outfall Sewer, Bermondsey Branch (2 plates), Outfall Sewer, Reservoir and Outlet (4 plates); Outfall Sewer, Filth Hoist; Sections of Sewers (North and South Sides).

THAMES EMBANKMENT.—Section of River Wall; Steamboat Pier, Westminster (2 plates), Landing Stairs between Charing Cross and Waterloo Bridges; York Gate (2 plates); Overflow and Outlet at Savoy Street Sewer (3 plates); Steamboat Pier, Waterloo Bridge (3 plates); Junction of Sewers, Plans and Sections; Gullies, Plans and Sections; Rolling Stock; Granite and Iron Forts.

"The drawings have a constantly increasing value, and whoever desires to possess clear representations of the two great works carried out by our Metropolitan Board will obtain Mr. Humber's volume."—*Engineer.*

HUMBER'S RECORD OF MODERN ENGINEERING. FOURTH SERIES. Imp. 4to, with 36 Double Plates, Photographic Portrait of John Fowler, late Pres. Inst. C.E., and copious descriptive Letterpress, Specifications, &c., £3 3s. half-morocco.

List of the Plates and Diagrams.

Abbey Mills Pumping Station, Main Drainage, Metropolis (4 plates); Barrow Docks (5 plates); Manquis Viaduct, Santiago and Valparaiso Railway (2 plates); Adam's Locomotive, St. Helen's Canal Railway (2 plates); Cannon Street Station Roof, Charing Cross Railway (3 plates); Road Bridge over the River Moka (2 plates); Telegraphic Apparatus for Mesopotamia; Viaduct over the River Wye, Midland Railway (3 plates); St. Germans Viaduct, Cornwall Railway (2 plates); Wrought-Iron Cylinder for Diving Bell; Millwall Docks (6 plates); Milroy's Patent Excavator; Metropolitan District Railway (6 plates); Harbours, Ports, and Breakwaters (3 plates).

"We gladly welcome another year's issue of this valuable publication from the able pen of Mr. Humber. The accuracy and general excellence of this work are well known, while its usefulness in giving the measurements and details of some of the latest examples of engineering, as carried out by the most eminent men in the profession, cannot be too highly prized."—*Artizan.*

Strains, Calculation of.

A HANDY BOOK FOR THE CALCULATION OF STRAINS IN GIRDERS AND SIMILAR STRUCTURES, AND THEIR STRENGTH. Consisting of Formulæ and Corresponding Diagrams, with numerous details for Practical Application, &c. By WILLIAM HUMBER, A-M. Inst. C.E., &c. Fourth Edition. Crown 8vo, nearly 100 Woodcuts and 3 Plates, 7s. 6d. cloth.

"The formulæ are neatly expressed, and the diagrams good."—*Athenæum.*

"We heartily commend this really *handy* book to our engineer and architect readers."—*English Mechanic.*

Barlow's Strength of Materials, enlarged by Humber

A TREATISE ON THE STRENGTH OF MATERIALS;

are added, Experiments by HODGKINSON, FAIRBAIRN, and KIRKALDY; and Formulæ for Calculating Girders, &c. Arranged and Edited by W. HUMBER, A-M. Inst. C.E. Demy 8vo, 400 pp., with 19 large Plates and numerous Woodcuts, 18s. cloth.

"Valuable alike to the student, tyro, and the experienced practitioner, it will always rank in future, as it has hitherto done, as the standard treatise on that particular subject."—*Engineer.*

"There is no greater authority than Barlow."—*Building News.*

"Deserves a foremost place on the bookshelves of every civil engineer."—*English Mechanic.*

Trigonometrical Surveying.

AN OUTLINE OF THE METHOD OF CONDUCTING A TRIGONOMETRICAL SURVEY, for the Formation of Geographical and Topographical Maps and Plans, Military Reconnaissance, Levelling, &c., with Useful Problems, Formulæ, and Tables. By Lieut.-General FROME, R.E. Fourth Edition, Revised and partly Re-written by Major General Sir CHARLES WARREN, G.C.M.G., R.E. With 19 Plates and 115 Woodcuts, royal 8vo, 16s. cloth.

"The simple fact that a fourth edition has been called for is the best testimony to its merits. No words of praise from us can strengthen the position so well and so steadily maintained by this work. Sir Charles Warren has revised the entire work, and made such additions as were necessary to bring every portion of the contents up to the present date."—*Broad Arrow.*

Oblique Bridges.

A PRACTICAL AND THEORETICAL ESSAY ON OBLIQUE BRIDGES. With 13 large Plates. By the late GEORGE WATSON BUCK, M.I.C.E. Third Edition, revised by his Son, J. H. WATSON BUCK, M.I.C.E.; and with the addition of Description to Diagrams for Facilitating the Construction of Oblique Bridges, by W. H. BARLOW, M.I.C.E. Royal 8vo, 12s. cloth.

"The standard text-book for all engineers regarding skew arches is Mr. Buck's treatise, and it would be impossible to consult a better."—*Engineer.*

"Mr. Buck's treatise is recognised as a standard text-book, and his treatment has divested the subject of many of the intricacies supposed to belong to it. As a guide to the engineer and architect, on a confessedly difficult subject, Mr. Buck's work is unsurpassed."—*Building News.*

Bridge Construction.

EXAMPLES OF BRIDGE AND VIADUCT CONSTRUCTION OF MASONRY, TIMBER, AND IRON. Consisting of 46 Plates from the Contract Drawings or Admeasurement of Select Works. By W. D. HASKOLL C.E. Second Edition, with the addition of 554 Estimates, and the Practice of Setting out Works. Illustrated with 6 pages of Diagrams. Imp. 4to, £2 12s. 6d. half-morocco.

"A work of the present nature by a man of Mr. Haskoll's experience must prove invaluable. The tables of estimates will considerably enhance its value."—*Engineering.*

Earthwork.

EARTHWORK TABLES. Showing the Contents in Cubic Yards of Embankments, Cuttings, &c., of Heights or Depths up to an average of 80 feet. By JOSEPH BROADBENT, C.E., and FRANCIS CAMPIN, C.E. Crown 8vo, 5s. cloth.

"The way in which accuracy is attained, by a simple division of each cross section into three elements, two in which are constant and one variable, is ingenious."—*Athenæum.*

Statics, Graphic and Analytic.

GRAPHIC AND ANALYTIC STATICS, in their Practical Application to the Treatment of Stresses in Roofs, Solid Girders, Lattice, Bowstring and Suspension Bridges, Braced Iron Arches and Piers, and other Frameworks. By R. HUDSON GRAHAM, C.E. Containing Diagrams and Plates to Scale. With numerous Examples, many taken from existing Structures. Specially arranged for Class-work in Colleges and Universities. Second Edition, Revised and Enlarged. 8vo, 16s. cloth.

"Mr. Graham's book will find a place wherever graphic and analytic statics are used or studied. —*Engineer*.

"This exhaustive treatise is admirably adapted for the architect and engineer, and will tend to wean the profession from a tedious and laboured mode of calculation."—*Building News*.

"The work is excellent from a practical point of view, and has evidently been prepared with much care. The directions for working are ample, and are illustrated by an abundance of well-selected examples. It is an excellent text-book for the practical draughtsman."—*Athenæum*.

Survey Practice.

AID TO SURVEY PRACTICE, for Reference in Surveying, Levelling, Setting-out and in Route Surveys of Travellers by Land and Sea. With Tables, Illustrations, and Records. By LOWIS D'A. JACKSON, A.M.I.C.E., Author of "Hydraulic Manual," "Modern Metrology," &c. Large crown 8vo, 12s. 6d. cloth.

"Mr. Jackson has produced a valuable *vade-mecum* for the surveyor. We can recommend this book as containing an admirable supplement to the teaching of the accomplished surveyor."—*Athenæum*.

"As a text-book we should advise all surveyors to place it in their libraries, and study well the matured instructions afforded in its pages."—*Colliery Guardian*

"The author brings to his work a fortunate union of theory and practical experience which, aided by a clear and lucid style of writing, renders the book a very useful one."—*Builder*.

Surveying, Land and Marine.

LAND AND MARINE SURVEYING, in Reference to the Preparation of Plans for Roads and Railways; Canals, Rivers, Towns' Water Supplies: Docks and Harbours. With Description and Use of Surveying Instruments. By W. DAVIS HASKOLL, C.E., Author of "Bridge and Viaduct Construction," &c. Second Edition, Revised, with Additions. Large crown 8vo, 9s. cloth.

"A most useful and well arranged book for the aid of a student. We can strongly recommend it as a carefully written and valuable text-book. It enjoys a well-deserved repute among surveyors." —*Builder*.

"This volume cannot fail to prove of the utmost practical utility. It may be safely recommended to all students who aspire to become clean and expert surveyors."—*Mining Journal*.

Levelling.

A TREATISE ON THE PRINCIPLES AND PRACTICE OF LEVELLING. Showing its Application to purposes of Railway and Civil Engineering, in the Construction of Roads; with Mr. TELFORD's Rules for the same. By FREDERICK W. SIMMS, F.G.S., M. Inst. C.E. Seventh Edition, with the addition of LAW's Practical Examples for Setting-out Railway Curves, and TRAUTWINE's Field Practice of Laying-out Circular Curves. With 7 Plates and numerous Woodcuts, 8vo, 8s. 6d. cloth. *** TRAUTWINE on Curves may be had separate, 5s.

ineer.

younger

ut the present edition of Mr. Simms's useful work."—*Engineering*

Tunnelling.

PRACTICAL TUNNELLING. Explaining in detail the Setting-out of the works, Shaft-sinking and Heading-driving, Ranging the Lines and Levelling underground, Sub-Excavating, Timbering, and the Construction of the Brickwork of Tunnels, with the amount of Labour required for, and the Cost of, the various portions of the work. By FREDERICK W. SIMMS, F.G.S., M. Inst. C.E. Third Edition, Revised and Extended by D. KINNEAR CLARK, M. Inst. C.E. Imp. 8vo, with 21 Folding Plates and numerous Wood Engravings, 30s. cloth.

"The estimation in which Mr. Simms's book has been held for over thirty years cannot be more truly expressed than in the words of the late Prof. Rankine:—'The best source of information on the subject of tunnels is Mr. F. W. Simms's work on Practical Tunnelling.'"—*Architect*.

"Mr. Clark has added immensely to the value of the book."—*Engineer*.

"The additional chapters by Mr. Clark, containing as they do numerous examples of modern practice, bring the book well up to date."—*Engineering*.

Heat, Expansion by.

EXPANSION OF STRUCTURES BY HEAT. By JOHN KEILY, C.E., late of the Indian Public Works and Victorian Railway Departments. Crown 8vo, 3s. 6d. cloth. [*Just published.*

SUMMARY OF CONTENTS.

Section I. FORMULAS AND DATA.
Section II. METAL BARS.
Section III. SIMPLE FRAMES.
Section IV. COMPLEX FRAMES AND PLATES.
Section V. THERMAL CONDUCTIVITY.
Section VI. MECHANICAL FORCE OF HEAT.
Section VII. WORK OF EXPANSION AND CONTRACTION.
Section VIII. SUSPENSION BRIDGES.
Section IX. MASONRY STRUCTURES.

"The aim the author has set before him, viz., to show the effects of heat upon metallic and other structures, is a laudable one, for this is a branch of physics upon which the engineer or architect can find but little reliable and comprehensive data in books."—*Builder.*

"Whoever is concerned to know the effect of changes of temperature on such structures as suspension bridges and the like, could not do better than consult Mr. Keily's valuable and handy exposition of the geometrical principles involved in these changes."—*Scotsman.*

Practical Mathematics.

MATHEMATICS FOR PRACTICAL MEN: Being a Commonplace Book of Pure and Mixed Mathematics. Designed chiefly for the use of Civil Engineers, Architects and Surveyors. By OLINTHUS GREGORY, LL.D., F.R.A.S., Enlarged by HENRY LAW, C.E. 4th Edition, carefully Revised by J. R. YOUNG, formerly Professor of Mathematics, Belfast College. With 13 Plates, 8vo, £1 1s., cloth.

"The engineer or architect will here find ready to his hand rules for solving nearly every mathe-[illegible]al difficulty that may arise in his practice. The rules are in all cases explained by means of [illegible]iples, in which every step of the process is clearly worked out."—*Builder.*

"One of the most serviceable books for practical mechanics. . . . It is an instructive book for the student, and a text-book for him who, having once mastered the subjects it treats of, needs occasionally to refresh his memory upon them."—*Building News.*

Hydraulic Tables.

HYDRAULIC TABLES, CO-EFFICIENTS, and FORMULÆ for finding the Discharge of Water from Orifices, Notches, Weirs, Pipes, and Rivers. With New Formulæ, Tables, and General Information on Rainfall, Catchment-Basins, Drainage, Sewerage, Water Supply for Towns and Mill Power. By JOHN NEVILLE, Civil Engineer, M.R.I.A. Third Edition, carefully revised, with considerable Additions. Numerous Illustrations. Crown 8vo, 14s. cloth.

"It is, of all English books on the subject, the one nearest to completeness. . . . From the good arrangement of the matter, the clear explanations, and abundance of formulæ, the carefully calculated tables, and, above all, the thorough acquaintance with both theory and construction, which is displayed from first to last, the book will be found to be an acquisition."—*Architect.*

River Engineering.

RIVER BARS: The Causes of their Formation, and their Treatment by "Induced Tidal Scour." With a Description of the Successful Reduction by this Method of the Bar at Dublin. By I. J. MANN, Assist. Eng. to the Dublin Port and Docks Board. Royal 8vo, 7s. 6d. cloth.

"We recommend all interested in harbour works—and, indeed, those concerned in the improvements of rivers generally—to read Mr. Mann's interesting work."—*Engineer.*

"A most valuable contribution to the history of this branch of engineering."—*Engineering and Mining Journal.*

Hydraulics.

HYDRAULIC MANUAL. Consisting of Working Tables and Explanatory Text. Intended as a Guide in Hydraulic Calculations and Field Operations. By LOWIS D'A. JACKSON, Author of "Aid to Survey Practice," "Modern Metrology," &c. Fourth Edition. Rewritten and Enlarged. Large crown 8vo, 16s. cloth.

"The author has been a careful observer of the facts which have come under his notice, as well as a painstaking collector and critic of the results of the experiments of others, and from the great mass of material at his command he has constructed a manual which may be accepted as a trustworthy guide to this branch of the engineer's profession."—*Engineering.*

"The standard work in this department of mechanics. The present edition has been brought abreast of the most recent practice."—*Scotsman.*

"The most useful feature of this work is its freedom from what is superannuated, and its thorough adoption of recent experiments; the text is, in fact, in great part a short account of the great modern experiments."—*Nature.*

Drainage.

ON THE DRAINAGE OF LANDS, TOWNS AND BUILDINGS. By G. D. DEMPSEY, C.E., Author of "The Practical Railway Engineer," &c. Revised, with large Additions on RECENT PRACTICE IN DRAINAGE ENGINEERING, by D. KINNEAR CLARK, M.Inst. C.E. Author of "Tramways: their Construction and Working," "A Manual of Rules, Tables, and Data for Mechanical Engineers," &c. &c. Crown 8vo, 7s. 6d. cloth. [*Just Published.*

"The new matter added to Mr Dempsey's excellent work is characterised by the comprehensive grasp and accuracy of detail for which the name of Mr. D. K Clark is a sufficient voucher."—*Athenæum*

"As a work on recent practice in drainage engineering, the book is to be commended to all who are making that branch of engineering science their special study"—*Iron.*

"A comprehensive manual on drainage engineering, and a useful introduction to the student." *Building News.*

Tramways and their Working.

TRAMWAYS: THEIR CONSTRUCTION AND WORKING. Embracing a Comprehensive History of the System; with an exhaustive Analysis of the various Modes of Traction, including Horse-Power, Steam, Heated Water, and Compressed Air; a Description of the Varieties of Rolling Stock; and ample Details of Cost and Working Expenses: the Progress recently made in Tramway Construction, &c. &c. By D. KINNEAR CLARK, M. Inst. C.E. With over 200 Wood Engravings, and 13 Folding Plates. Two Vols., large crown 8vo, 30s. cloth.

"All interested in tramways must refer to it, as all railway engineers have turned to the author's work 'Railway Machinery.'"—*Engineer.*

"An exhaustive and practical work on tramways, in which the history of this kind of locomotion, and a description and cost of the various modes of laying tramways, are to be found."—*Building News.*

"The best form of rails, the best mode of construction, and the best mechanical appliances are so fairly indicated in the work under review, that any engineer about to construct a tramway will be enabled at once to obtain the practical information which will be of most service to him."—*Athenæum.*

Oblique Arches.

A PRACTICAL TREATISE ON THE CONSTRUCTION OF OBLIQUE ARCHES. By JOHN HART. Third Edition, with Plates. Imperial 8vo, 8s. cloth.

Curves, Tables for Setting-out.

TABLES OF TANGENTIAL ANGLES AND MULTIPLES for Setting-out Curves from 5 to 200 Radius. By ALEXANDER BEAZELEY, M. Inst. C.E. Third Edition. Printed on 48 Cards, and sold in a cloth box, waistcoat-pocket size, 3s. 6d.

"Each table is printed on a small card, which, being placed on the theodolite, leaves the hands free to manipulate the instrument—no small advantage as regards the rapidity of work"—*Engineer*

"Very handy; a man may know that all his day's work must fall on two of these cards, which he puts into his own card-case, and leaves the rest behind."—*Athenæum.*

Engineering Fieldwork.

THE PRACTICE OF ENGINEERING FIELDWORK, applied to Land and Hydraulic, Hydrographic, and Submarine Surveying and Levelling. Second Edition, Revised, with considerable Additions, and a Supplement on Waterworks, Sewers, Sewage, and Irrigation. By W. DAVIS HASKOLL, C.E. Numerous Folding Plates. In One Volume, demy 8vo, £1 5s. cloth.

Tunnel Shafts.

THE CONSTRUCTION OF LARGE TUNNEL SHAFTS: A Practical and Theoretical Essay. By J. H. WATSON BUCK, M. Inst. C.E., Resident Engineer, London and North-Western Railway. Illustrated with Folding Plates, royal 8vo, 12s. cloth

"Many of the methods given are of extreme practical value to the mason; and the observations on the form of arch, the rules for ordering the stone, and the construction of the templates will be found of considerable use. We commend the book to the engineering profession."—*Building News.*

"Will be regarded by civil engineers as of the utmost value, and calculated to save much time and obviate many mistakes."—*Colliery Guardian.*

Girders, Strength of.

GRAPHIC TABLE FOR FACILITATING THE COMPUTATION OF THE WEIGHTS OF WROUGHT IRON AND STEEL GIRDERS, etc., for Parliamentary and other Estimates. By J. H. WATSON BUCK, M. Inst. C.E. On a Sheet, 2s. 6d.

Trusses.

TRUSSES OF WOOD AND IRON. Practical Applications of Science in Determining the Stresses, Breaking Weights, Safe Loads, Scantlings, and Details of Construction, with Complete Working Drawings. By WILLIAM GRIFFITHS, Surveyor, Assistant Master, Tranmere School of Science and Art. Oblong 8vo, 4s. 6d. cloth.

"This handy little book enters so minutely into every detail connected with the construction of roof trusses, that no student need be ignorant of these matters for want of an easy source to come at the knowledge."—*Practical Engineer.*

"From the manner of treating the subject, Mr. Griffiths' book is clear enough to enable a student to be his own teacher. It will be useful in the science school and in workshops."—*Architect.*

Railway Working.

SAFE RAILWAY WORKING. A Treatise on Railway Accidents: Their Cause and Prevention; with a Description of Modern Appliances and Systems. By CLEMENT E. STRETTON, C.E., Vice-President and Consulting Engineer, Amalgamated Society of Railway Servants. With Illustrations and Coloured Plates, crown 8vo, 4s. 6d. strongly bound.

OUTLINE OF CONTENTS.

Chapter I. SUMMARY OF ACCIDENTS, 1885.—II. PERMANENT WAY.—III. SIGNALLING; BLOCK SYSTEM.—IV. CONTINUOUS BRAKES.—V. BREAKING OF RAILWAY AXLES.—VI. RAILWAY COUPLINGS.—VII. RAILWAY SERVANTS AND THE LAW OF MANSLAUGHTER.—Appendix I. RAILWAY TRAFFIC RETURNS.—II. RAILWAY SIGNAL RETURNS.—III. CONTINUOUS BRAKES RETURNS.—IV. MIXED TRAINS.

*** OPINIONS OF THE PRESS.

"A book for the engineer, the directors, the managers; and, in short, all who wish for information on railway matters will find a perfect encyclopædia in 'Safe Railway Working.'"—*Railway Review.*

"Mr Clement E. Stretton, the energetic Vice-President of the Amalgamated Society of Railway Servants, may be congratulated on having collected, in a very convenient form, much valuable information on the principal questions affecting the safe working of railways."—*Railway Engineer.*

"We commend the remarks on railway signalling to all railway managers, especially where a uniform code and practice is advocated."—*Herepath's Railway Journal.*

Field-Book for Engineers.

THE ENGINEER'S, MINING SURVEYOR'S, AND CONTRACTOR'S FIELD-BOOK. Consisting of a Series of Tables, with Rules, Explanations of Systems, and use of Theodolite for Traverse Surveying and Plotting the Work with minute accuracy by means of Straight Edge and Set Square only; Levelling with the Theodolite, Casting-out and Reducing Levels to Datum, and Plotting Sections in the ordinary manner; setting-out Curves with the Theodolite by Tangential Angles and Multiples, with Right and Left-hand Readings of the Instrument: Setting-out Curves without Theodolite, on the System of Tangential Angles by sets of Tangents and Offsets: and Earthwork Tables to 80 feet deep, calculated for every 6 inches in depth. By W. DAVIS HASKOLL, C.E. With numerous Woodcuts. Fourth Edition, Enlarged. Crown 8vo, 12s. cloth.

"The book is very handy, and the author might have added that the separate tables of sines and tangents to every minute will make it useful for many other purposes, the genuine traverse tables existing all the same."—*Athenæum.*

"Every person engaged in engineering field operations will estimate the importance of such a work and the amount of valuable time which will be saved by reference to a set of reliable tables prepared with the accuracy and fulness of those given in this volume."—*Railway News.*

Earthwork, Measurement of.

A MANUAL ON EARTHWORK. By ALEX. J. S. GRAHAM, C.E. With numerous Diagrams. 18mo, 2s. 6d. cloth.

"A great amount of practical information, very admirably arranged, and available for rough estimates, as well as for the more exact calculations required in the engineer's and contractor's offices."—*Artisan.*

Strains in Ironwork.

THE STRAINS ON STRUCTURES OF IRONWORK; with Practical Remarks on Iron Construction. By F. W. SHEILDS, M. Inst. C.E. Second Edition, with 5 Plates. Royal 8vo, 5s. cloth.

"The student cannot find a better little book on this subject."—*Engineer.*

Cast Iron and other Metals, Strength of.

A PRACTICAL ESSAY ON THE STRENGTH OF CAST IRON AND OTHER METALS. By THOMAS TREDGOLD, C.E. Fifth Edition, including HODGKINSON'S Experimental Researches. 8vo, 12s. cloth.

ARCHITECTURE, BUILDING, etc.

Construction.

THE SCIENCE OF BUILDING: An Elementary Treatise on the Principles of Construction. By E. WYNDHAM TARN, M.A., Architect. Second Edition, Revised, with 58 Engravings. Crown 8vo, 7s. 6d. cloth.

"A very valuable book, which we strongly recommend to all students."—*Builder.*

"No architectural student should be without this handbook of constructional knowledge."—*Architect.*

Villa Architecture.

A HANDY BOOK OF VILLA ARCHITECTURE: Being a Series of Designs for Villa Residences in various Styles. With Outline Specifications and Estimates. By C. WICKES, Architect, Author of "The Spires and Towers of England," &c. 61 Plates, 4to, £1 11s. 6d. half-morocco, gilt edges.

"The whole of the designs bear evidence of their being the work of an artistic architect, and they will prove very valuable and suggestive."—*Building News.*

Text-Book for Architects.

THE ARCHITECT'S GUIDE: Being a Text-Book of Useful Information for Architects, Engineers, Surveyors, Contractors, Clerks of Works, &c. &c. By FREDERICK ROGERS, Architect, Author of "Specifications for Practical Architecture," &c. Second Edition, Revised and Enlarged. With numerous Illustrations. Crown 8vo, 6s. cloth.

"As a text-book of useful information for ar hitects, engineers, surveyors, &c., it would be hard to find a handier or more complete little volu ."—*Standard.*

"A young architect could hardly have a better guide-book."—*Timber Trades Journal.*

Taylor and Cresy's Rome.

THE ARCHITECTURAL ANTIQUITIES OF ROME. By the late G. L. TAYLOR, Esq., F.R.I.B.A., and EDWARD CRESY, Esq. New

N.B.—This is the only book which gives on a large scale, and with the precision of architectural measurement, the principal Monuments of Ancient Rome in plan, elevation, and detail.

"Taylor and Cresy's work has from its first publication been ranked among those professional books which cannot be bettered. . . . It would be difficult to find examples of drawings, even among those of the most painstaking students of Gothic, more thoroughly worked out than are the one hundred and thirty plates in this volume."—*Architect.*

Architectural Drawing.

PRACTICAL RULES ON DRAWING, for the Operative Builder and Young Student in Architecture. By GEORGE PYNE. With 14 Plates, 4to, 7s. 6d. boards.

Civil Architecture.

THE DECORATIVE PART OF CIVIL ARCHITECTURE. By Sir WILLIAM CHAMBERS, F.R.S. With Illustrations, Notes, and an Examination of Grecian Architecture, by JOSEPH GWILT, F.S.A. Edited by W. H. LEEDS. 66 Plates, 4to, 21s. cloth.

House Building and Repairing.

THE HOUSE-OWNER'S ESTIMATOR; or, What will it Cost to Build, Alter, or Repair? fessional People, as well the late JAMES D. SIMON MILLER, A.R.I.B.A. With numerous Illustrations. Third Edition, Revised. Crown 8vo, 3s. 6d. cloth.

"In two years it will repay its cost a hundred times over"—*Field.*

"A very handy book."—*English Mechanic.*

Designing, Measuring, and Valuing.

THE STUDENT'S GUIDE to the PRACTICE of MEASURING AND VALUING ARTIFICERS' WORKS. Containing Directions for taking Dimensions, Abstracting the same, and bringing the Quantities into Bill, with Tables of Constants, and copious Memoranda for the Valuation of Labour and Materials in the respective Trades of Bricklayer and Slater, Carpenter and Joiner, Painter and Glazier, Paperhanger, &c. With 8 Plates and 63 Woodcuts. Originally edited by EDWARD DOBSON, Architect. Fifth Edition, Revised, with considerable Additions on Mensuration and Construction, and a New Chapter on Dilapidations, Repairs, and Contracts, by E. WYNDHAM TARN, M.A. Crown 8vo, 9s. cloth.

"Well fulfils the promise of its title-page, and we can thoroughly recommend it to the class for whose use it has been compiled. Mr. Tarn's additions and revisions have much increased the usefulness of the work, and have especially augmented its value to students."—*Engineering.*

"The work has been carefully revised and edited by Mr. E. Wyndham Tarn, M.A., and comprises several valuable additions on construction, mensuration, dilapidations and repairs, and other matters. . . . This edition will be found the most complete treatise on the principles of measuring and valuing artificers' work that has yet been published."—*Building News.*

Pocket Estimator and Technical Guide.

THE POCKET TECHNICAL GUIDE, MEASURER AND ESTIMATOR FOR BUILDERS AND SURVEYORS. Containing Technical Directions for Measuring Work in all the Building Trades, with a Treatise on the Measurement of Timber and Complete Specifications for Houses, Roads, and Drains, and an easy Method of Estimating the various parts of a Building collectively. By A. C. BEATON, Author of "Quantities and Measurements," &c. Fourth Edition, carefully Revised and Priced according to the Present Value of Materials and Labour, with 53 Woodcuts, leather, waistcoat-pocket size, 1s. 6d. gilt edges.

"No builder, architect, surveyor, or valuer should be without his 'Beaton's Guide.'"—*Building News.*

"Contains an extraordinary amount of information in daily requisition in measuring and estimating. Its presence in the pocket will save valuable time and trouble."—*Building World.*

"An exceedingly handy pocket companion, thoroughly reliable."—*Builder's Weekly Reporter.*

"This neat little compendium contains all that is requisite in carrying out contracts for excavating, tiling, bricklaying, paving, &c."—*British Trade Journal.*

Donaldson on Specifications.

THE HANDBOOK OF SPECIFICATIONS; or, Practical Guide to the Architect, Engineer, Surveyor, and Builder, in drawing up Specifications and Contracts for Works and Constructions. Illustrated by Precedents of Buildings actually executed by eminent Architects and Engineers. By Professor T. L. DONALDSON, P.R.I.B.A., &c. New Edition, in One large Vol., 8vo, with upwards of 1,000 pages of Text, and 33 Plates, £1 11s. 6d. cloth.

"In this work forty-four specifications of executed works are given, including the specifications for parts of the new Houses of Parliament, by Sir Charles Barry, and for the new Royal Exchange, by Mr. Tite, M.P. The latter, in particular, is a very complete and remarkable document. It embodies, to a great extent, as Mr. Donaldson mentions, 'the bill of quantities with the description of the works.' . . . It is valuable as a record, and more valuable still as a book of precedents. . . . Suffice it to say that Donaldson's 'Handbook of Specifications' must be bought by all architects."—*Builder.*

Bartholomew and Rogers' Specifications.

SPECIFICATIONS FOR PRACTICAL ARCHITECTURE. A Guide to the Architect, Engineer, Surveyor, and Builder. With an Essay on the Structure and Science of Modern Buildings. Upon the Basis of the Work by ALFRED BARTHOLOMEW, thoroughly Revised, Corrected, and greatly added to by FREDERICK ROGERS, Architect. Second Edition, Revised, with Additions. With numerous Illusts., medium 8vo, 15s. cloth.

"The collection of specifications prepared by Mr. Rogers on the basis of Bartholomew's work is too well known to need any recommendation from us. It is one of the books with which every young architect must be equipped; for time has shown that the specifications cannot be set aside through any defect in them."—*Architect.*

"Good forms for specifications are of considerable value, and it was an excellent idea to compile a work on the subject upon the basis of the late Alfred Bartholomew's valuable work. The second edition of Mr. Rogers's book is evidence of the want of a book dealing with modern requirements and materials."—*Building News.*

Geometry for the Architect, Engineer, etc.

PRACTICAL GEOMETRY, for the Architect, Engineer and Mechanic. Giving Rules for the Delineation and Application of various Geometrical Lines, Figures and Curves. By E. W. TARN, M.A., Architect, Author of "The Science of Building," &c. Second Edition. With Appendices on Diagrams of Strains and Isometrical Projection. With 172 Illustrations, demy 8vo, 9s. cloth.

"No book with the same objects in view has ever been published in which the clearness of the rules laid down and the illustrative diagrams have been so satisfactory."—*Scotsman.*

"This is a manual for the practical man, whether architect, engineer, or mechanic. . . . The object of the author being to avoid all abstruse formulæ or complicated methods, and to enable persons with but a moderate knowledge of geometry to work out the problems required."—*English Mechanic.*

The Science of Geometry.

THE GEOMETRY OF COMPASSES; or, Problems Resolved by the mere Description of Circles, and the use of Coloured Diagrams and Symbols. By OLIVER BYRNE. Coloured Plates. Crown 8vo, 3s. 6d. cloth.

"The treatise is a good one, and remarkable—like all Mr Byrne's contributions to the science of geometry—for the lucid character of its teaching."—*Building News.*

DECORATIVE ARTS, etc.

Woods and Marbles (Imitation of).

SCHOOL OF PAINTING FOR THE IMITATION OF WOODS AND MARBLES, as Taught and Practised by A. R. VAN DER BURG and P. VAN DER BURG, Directors of the Rotterdam Painting Institution. Royal folio, 18½ by 12½ in., Illustrated with 24 full-size Coloured Plates; also 12 plain Plates, comprising 154 Figures. Second and Cheaper Edition. Price £1 11s. 6d.

List of Plates.

1. Various Tools required for Wood Painting—2, 3. Walnut. Preliminary Stages of Graining and Finished Specimen—4. Tools used for Marble Painting and Method of Manipulation—5, 6. St. Remi Marble: Earlier Operations and Finished Specimen—7. Methods of Sketching different Grains, Knots, &c—8, 9. Ash: Preliminary Stages and Finished Specimen—10. Methods of Sketching Marble Grains—11, 12. Breche Marble Preliminary Stages of Working and Finished Specimen—13. Maple: Methods of Producing the different Grains—14, 15. Bird's eye Maple: Preliminary Stages and Finished Specimen—16. Methods of Sketching the different Species of White Marble—17, 18. White Marble: Preliminary Stages of Process and Finished Specimen—19. Mahogany: Specimens of various Grains and Methods of Manipulation—20, 21. Mahogany: Earlier Stages and Finished Specimen—22, 23, 24. Sienna Marble: Varieties of Grain, Preliminary Stages and Finished Specimen—25, 26, 27. Juniper Wood: Methods of producing Grain, &c.: Preliminary Stages and Finished Specimen—28, 29, 30. Vert de Mer Marble. Varieties of Grain and Methods of Working Unfinished and Finished Specimens—31. 32 33. Oak: Varieties of Grain, Tools Employed, and Methods of Manipulation, Preliminary Stages and Finished Specimen—34, 35, 36. Waulsort Marble: Varieties of Grain, Unfinished and Finished Specimens.

*** OPINIONS OF THE PRESS.

"Those who desire to attain skill in the art of painting woods and marbles will find advantage in consulting this book. . . . Some of the Working Men's Clubs should give their young men the opportunity to study it."—*Builder.*

"A comprehensive guide to the art. The explanations of the processes, the manipulation and management of the colours, and the beautifully executed plates will not be the least valuable to the student who aims at making his work a faithful transcript of nature."—*Building News.*

"Students and novices are fortunate who are able to become the possessors of *so noble a work.*"—*Architect.*

House Decoration.

ELEMENTARY DECORATION. A Guide to the Simpler Forms of Everyday Art, as applied to the Interior and Exterior Decoration of Dwelling Houses, &c. By JAMES W. FACEY, Jun. With 68 Cuts. 12mo, 2s. cloth limp.

"As a technical guide-book to the decorative painter it will be found reliable."—*Building News.*

PRACTICAL HOUSE DECORATION: A Guide to the Art of Ornamental Painting, the Arrangement of Colours in Apartments, and the principles of Decorative Design. With some Remarks upon the Nature and Properties of Pigments. By JAMES WILLIAM FACEY, Author of "Elementary Decoration," &c. With numerous Illustrations. 12mo, 2s. 6d. cloth limp.

N.B.—The above Two Works together in One Vol., strongly half-bound, 5s.

Colour.

A GRAMMAR OF COLOURING. Applied to Decorative Painting and the Arts. By GEORGE FIELD. New Edition, Revised, Enlarged, and adapted to the use of the Ornamental Painter and Designer. By ELLIS A. DAVIDSON. With New Coloured Diagrams and Engravings. 12mo, 3s. 6d. cloth boards.

"The book is a most useful *resume* of the properties of pigments."—*Builder.*

House Painting, Graining, etc.

HOUSE PAINTING, GRAINING, MARBLING, AND SIGN WRITING, A Practical Manual of. By ELLIS A. DAVIDSON. Fifth Edition. With Coloured Plates and Wood Engravings. 12mo, 6s. cloth boards.

"A mass of information, of use to the amateur and of value to the practical man."—*English Mechanic.*

"Simply invaluable to the youngster entering upon this particular calling, and highly serviceable to the man who is practising it."—*Furniture Gazette.*

Decorators, Receipts for.

THE DECORATOR'S ASSISTANT: A Modern Guide to Decorative Artists and Amateurs, Painters, Writers, Gilders, &c. Containing upwards of 600 Receipts, Rules and Instructions; with a variety of Information for General Work connected with every Class of Interior and Exterior Decorations, &c. 152 pp., crown 8vo, 1s. in wrapper.

"Full of receipts of value to decorators, painters, gilders, &c. The book contains the gist of larger treatises on colour and technical processes. It would be difficult to meet with a work so full of varied information on the painter's art."—*Building News.*

"We recommend the work to all who, whether for pleasure or profit, require a guide to decoration."—*Plumber and Decorator.*

Moyr Smith on Interior Decoration.

ORNAMENTAL INTERIORS, ANCIENT AND MODERN. By J. MOYR SMITH. Super-royal 8vo, with 32 full-page Plates and numerous smaller Illusts., handsomely bound in cloth, gilt top, price 18s. [*Just published.*

☞ *In* "ORNAMENTAL INTERIORS" *the designs of more than thirty artist-decorators and architects of high standing have been illustrated. The book may therefore fairly claim to give a good general view of the works of the modern school of decoration, besides giving characteristic examples of earlier decorative arrangements.*

"ORNAMENTAL INTERIORS" *gives a short account of the styles of Interior Decoration as practised by the Ancients in Egypt, Greece, Assyria, Rome and Byzantium. This part is illustrated by characteristic designs. The main body of the work, however, is devoted to the illustration of the modern styles of Decorative Art, and many examples are given of decorative designs suitable for modern Dining-Rooms, Drawing-Rooms, Libraries, Staircases and Halls, Parlours, Studies and Smoking-Rooms. The Decoration of Public Buildings is illustrated by views of the chief State Apartments in Buckingham Palace and Windsor Castle, the Salle de Leys at Antwerp, the Salle de Mariages at Brussels, and of other works which have distinctive features suitable for the purpose.*

*** OPINIONS OF THE PRESS.

"The book is well illustrated and handsomely got up, and contains some true criticism and a good many good examples of decorative treatment."—*The Builder.*

"We can greatly commend Mr Moyr Smith's book, for it is the production of one professedly capable in decorative work, and abounds with useful hints and descriptions of executed modern work, together with a well-put *resume* of ancient styles. . . . As much a book for the drawing-room as for the manufacturer."—*The British Architect.*

"Well fitted for the dilettante, amateur, and professional designer."—*Decoration.*

"This is the most elaborate, and beautiful work on the artistic decoration of interiors that we have seen . . . The scrolls, panels and other designs from the author's own pen are very beautiful and chaste; but he takes care that the designs of other men shall figure even more than his own."—*Liverpool Albion.*

"To all who take an interest in elaborate domestic ornament this handsome volume will be welcome."—*Graphic.*

"Mr Moyr Smith deserves the thanks of art workers for having placed within their reach a book that seems eminently adapted to afford, by example and precept, that guidance of which most craftsmen stand in need."—*Furniture Gazette.*

British and Foreign Marbles.

MARBLE DECORATION and the Terminology of British and Foreign Marbles. A Handbook for Students. By GEORGE H. BLAGROVE, Author of "Shoring and its Application," &c. With 28 Illustrations. Crown 8vo, 3s. 6d. cloth. [*Just published.*

DELAMOTTE'S WORKS ON ILLUMINATION AND ALPHABETS.

A PRIMER OF THE ART OF ILLUMINATION, for the Use of Beginners: with a Rudimentary Treatise on the Art, Practical Directions for its exercise, and Examples taken from Illuminated MSS., printed in Gold and Colours. By F. DELAMOTTE. New and Cheaper Edition. Small 4to, 6*s.* ornamental boards.

"The examples of ancient MSS. recommended to the student, which, with much good sense, the author chooses from collections accessible to all, are selected with judgment and knowledge, as well as taste."—*Athenæum.*

ORNAMENTAL ALPHABETS, Ancient and Mediæval, from the Eighth Century, with Numerals; including Gothic, Church-Text, large and small, German, Italian, Arabesque, Initials for Illumination, Monograms, Crosses, &c. &c., for the use of Architectural and Engineering Draughtsmen, Missal Painters, Masons, Decorative Painters, Lithographers, Engravers, Carvers, &c. &c. Collected and Engraved by F. DELAMOTTE, and printed in Colours. New and Cheaper Edition. Royal 8vo, oblong, 2*s.* 6*d.* ornamental boards.

"For those who insert enamelled sentences round gilded chalices, who blazon shop legends over shop-doors, who letter church walls with pithy sentences from the Decalogue, this book will be useful."—*Athenæum.*

EXAMPLES OF MODERN ALPHABETS, Plain and Ornamental; including German, Old English, Saxon, Italic, Perspective, Greek, Hebrew, Court Hand, Engrossing, Tuscan, Riband, Gothic, Rustic, and Arabesque; with several Original Designs, and an Analysis of the Roman and Old English Alphabets, large and small, and Numerals, for the use of Draughtsmen, Surveyors, Masons, Decorative Painters, Lithographers, Engravers, Carvers, &c. Collected and Engraved by F. DELAMOTTE, and printed in Colours. New and Cheaper Edition. Royal 8vo, oblong, 2*s.* 6*d.* ornamental boards.

"There is comprised in it every possible shape into which the letters of the alphabet and numerals can be formed, and the talent which has been expended in the conception of the various plain and ornamental letters is wonderful."—*Standard.*

MEDIÆVAL ALPHABETS AND INITIALS FOR ILLUMINATORS. By F. G. DELAMOTTE. Containing 21 Plates and Illuminated Title, printed in Gold and Colours. With an Introduction by J. WILLIS BROOKS. Fourth and Cheaper Edition. Small 4to, 4*s.* ornamental boards.

"A volume in which the letters of the alphabet come forth glorified in gilding and all the colours of the prism interwoven and intertwined and intermingled."—*Sun.*

THE EMBROIDERER'S BOOK OF DESIGN. Containing Initials, Emblems, Cyphers, Monograms, Ornamental Borders, Ecclesiastical Devices, Mediæval and Modern Alphabets, and National Emblems. Collected by F. DELAMOTTE, and printed in Colours. Oblong royal 8vo, 1*s.* 6*d.* ornamental wrapper.

"The book will be of great assistance to ladies and young children who are endowed with the art of plying the needle in this most ornamental and useful pretty work."—*East Anglian Times.*

Wood Carving.

INSTRUCTIONS IN WOOD-CARVING, for Amateurs; with Hints on Design. By A LADY. With Ten large Plates, 2*s.* 6*d.* in emblematic wrapper.

"The handicraft of the wood-carver, so well as a book can impart it, may be learnt from 'A Lady's' publication."—*Athenæum.*

"The directions given are plain and easily understood."—*English Mechanic.*

Glass Painting.

GLASS STAINING AND THE ART OF PAINTING ON GLASS. From the German of Dr. GESSERT and EMANUEL OTTO FROMBERG. With an Appendix on THE ART OF ENAMELLING. 12mo, 2*s.* 6*d.* cloth limp.

Letter Painting.

THE ART OF LETTER PAINTING MADE EASY. By JAMES GREIG BADENOCH. With 12 full-page Engravings of Examples, 1*s.* cloth limp.

"The system is a simple one, but quite original, and well worth the careful attention of letter-painters. It can be easily mastered and remembered."—*Building News.*

CARPENTRY, TIMBER, etc.

Tredgold's Carpentry, Enlarged by Tarn.

THE ELEMENTARY PRINCIPLES OF CARPENTRY. A Treatise on the Pressure and Equilibrium of Timber Framing, the Resistance of Timber, and the Construction of Floors, Arches, Bridges, Roofs, Uniting Iron and Stone with Timber, &c. To which is added an Essay on the Nature and Properties of Timber, &c., with Descriptions of the kinds of Wood used in Building; also numerous Tables of the Scantlings of Timber for different purposes, the Specific Gravities of Materials, &c. By THOMAS TREDGOLD, C.E. With an Appendix of Specimens of Various Roofs of Iron and Stone, Illustrated. Seventh Edition, thoroughly revised and considerably enlarged by E. WYNDHAM TARN, M.A., Author of "The Science of Building," &c. With 61 Plates, Portrait of the Author, and several Woodcuts. In one large vol., 4to, price £1 5s. cloth.

"Ought to be in every architect's and every builder's library."—*Builder.*

"A work whose monumental excellence must commend it wherever skilful carpentry is concerned. The author's principles are rather confirmed than impaired by time. The additional plates are of great intrinsic value."—*Building News.*

Woodworking Machinery.

WOODWORKING MACHINERY: Its Rise, Progress, and Construction. With Hints on the Management of Saw Mills and the Economical Conversion of Timber. Illustrated with Examples of Recent Designs by leading English, French, and American Engineers. By M. POWIS BALE, A.M. Inst. C.E., M.I.M.E. Large crown 8vo, 12s. 6d. cloth.

"Mr. Bale is evidently an expert on the subject, and he has collected so much information that his book is all-sufficient for builders and others engaged in the conversion of timber."—*Architect.*

"The most comprehensive compendium of wood-working machinery we have seen. The author is a thorough master of his subject."—*Building News.*

"The appearance of this book at the present time will, we should think, give a considerable impetus to the onward march of the machinist engaged in the designing and manufacture of wood-working machines. It should be in the office of every wood-working factory."—*English Mechanic.*

Saw Mills.

SAW MILLS: Their Arrangement and Management, and the Economical Conversion of Timber. (Being a Companion Volume to "Woodworking Machinery.") By M. POWIS BALE, A.M. Inst. C.E., M.I.M.E. With numerous Illustrations. Crown 8vo, 10s. 6d. cloth.

"The *administration* of a large sawing establishment is discussed, and the subject examined from a financial standpoint. Hence the size, shape, order, and disposition of saw-mills and the like are gone into in detail, and the course of the timber is traced from its reception to its delivery in its converted state. We could not desire a more complete or practical treatise."—*Builder.*

"We highly recommend Mr. Bale's work to the attention and perusal of all those who are engaged in the art of wood conversion, or who are about building or remodelling saw-mills on improved principles."—*Building News.*

Carpentering.

THE CARPENTER'S NEW GUIDE; or, Book of Lines for Carpenters; comprising all the Elementary Principles essential for acquiring a knowledge of Carpentry. Founded on the late PETER NICHOLSON'S Standard Work. A New Edition, revised by ARTHUR ASHPITEL, F.S.A. Together with Practical Rules on Drawing, by GEORGE PYNE. With 74 Plates, 4to, £1 1s. cloth.

Handrailing.

A PRACTICAL TREATISE ON HANDRAILING: Showing New and Simple Methods for Finding the Pitch of the Plank, Drawing the Moulds, Bevelling, Jointing-up, and Squaring the Wreath. By GEORGE COLLINGS. Illustrated with Plates and Diagrams. 12mo, 1s. 6d. cloth limp.

"Will be found of practical utility in the execution of this difficult branch of joinery."—*Builder.*

"Almost every difficult phase of this somewhat intricate branch of joinery is elucidated by the aid of plates and explanatory letterpress."—*Furniture Gazette.*

Circular Work.

CIRCULAR WORK IN CARPENTRY AND JOINERY: A Practical Treatise on Circular Work of Single and Double Curvature. By GEORGE COLLINGS, Author of "A Practical Treatise on Handrailing." Illustrated with numerous Diagrams. 12mo, 2s. 6d. cloth limp. [*Just published.*

"An excellent example of what a book of this kind should be. Cheap in price, clear in definition, and practical in the examples selected."—*Builder.*

Timber Merchant's Companion.

THE TIMBER MERCHANT'S AND BUILDER'S COMPANION. Containing New and Copious Tables of the Reduced Weight and Measurement of Deals and Battens, of all sizes, from One to a Thousand Pieces, and the relative Price that each size bears per Lineal Foot to any given Price per Petersburg Standard Hundred; the Price per Cube Foot of Square Timber to any given Price per Load of 50 Feet; the proportionate Value of Deals and Battens by the Standard, to Square Timber by the Load of 50 Feet; the readiest mode of ascertaining the Price of Scantling per Lineal Foot of any size, to any given Figure per Cube Foot, &c. &c. By WILLIAM DOWSING. Fourth Edition, Revised and Corrected. Cr. 8vo, 3s. cl.

"Every timber merchant and builder ought to possess it."—*Hull Advertiser.*

"We are glad to see a fourth edition of these admirable tables, which for correctness and simplicity of arrangement leave nothing to be desired."—*Timber Trades Journal.*

"An exceedingly well-arranged, clear, and concise manual of tables for the use of all who buy or sell timber."—*Journal of Forestry.*

Practical Timber Merchant.

THE PRACTICAL TIMBER MERCHANT. Being a Guide for the use of Building Contractors, Surveyors, Builders, &c., comprising useful Tables for all purposes connected with the Timber Trade, Marks of Wood, Essay on the Strength of Timber, Remarks on the Growth of Timber, &c. By W. RICHARDSON. Fcap 8vo, 3s. 6d. cloth.

"This handy manual contains much valuable information for the use of timber merchants, builders, foresters, and all others connected with the growth, sale, and manufacture of timber.'—*Journal of Forestry.*

Timber Freight Book.

THE TIMBER MERCHANT'S, SAW MILLER'S, AND IMPORTER'S FREIGHT BOOK AND ASSISTANT. Comprising Rules, Tables, and Memoranda relating to the Timber Trade. By WILLIAM RICHARDSON Timber Broker; together with a Chapter on "SPEEDS OF SAW MILL MACHINERY," by M. POWIS BALE, M.I.M.E., &c. 12mo, 3s. 6d. cl. boards.

"A very useful manual of rules, tables, and memoranda, relating to the timber trade. We recommend it as a compendium of calculation to all timber measurers and merchants, and as supplying a real want in the trade."—*Building News.*

Packing-Case Makers, Tables for.

PACKING-CASE TABLES; showing the number of Superficial Feet in Boxes or Packing-Cases, from six inches square and upwards. By W. RICHARDSON, Timber Broker. Second Edition. Oblong 4to, 3s. 6d. cl.

"Invaluable labour-saving tables."—*Ironmonger.* "Will save much labour."—*Grocer.*

Superficial Measurement.

THE TRADESMAN'S GUIDE TO SUPERFICIAL MEASUREMENT. Tables calculated from 1 to 200 inches in length, by 1 to 108 inches in breadth. For the use of Architects, Surveyors, Engineers, Timber Merchants, Builders, &c. By JAMES HAWKINGS. Third Edition. Fcap., 3s. 6d. cloth.

"A useful collection of tables to facilitate rapid calculation of surfaces. The exact area of any surface of which the limits have been ascertained can be instantly determined. The book will be found of the greatest utility to all engaged in building operations."—*Scotsman.*

Forestry.

THE ELEMENTS OF FORESTRY. Designed to afford Information concerning the Planting and Care of Forest Trees for Ornament or Profit, with Suggestions upon the Creation and Care of Woodlands. By F. B. HOUGH. Large crown 8vo, 10s. cloth.

Timber Importer's Guide.

THE TIMBER IMPORTER'S, TIMBER MERCHANT'S AND BUILDER'S STANDARD GUIDE. By RICHARD E. GRANDY. Comprising an Analysis of Deal Standards, Home and Foreign, with Comparative Values and Tabular Arrangements for fixing Nett Landed Cost on Baltic and North American Deals, including all intermediate Expenses, Freight, Insurance, &c. &c. Together with copious Information for the Retailer and Builder. Third Edition, Revised. 12mo, 2s. 6d. cloth boards.

"Everything it pretends to be: built up gradually, it leads one from a forest to a treenail, and throws in, as a makeweight, a host of material concerning bricks, columns, cisterns, &c."—*English Mechanic.*

NAVAL ARCHITECTURE, NAVIGATION, etc.

Chain Cables.

CHAIN CABLES AND CHAINS. Comprising Sizes and Curves of Links, Studs, &c., Iron for Cables and Chains, Chain Cable and Chain Making, Forming and Welding Links, Strength of Cables and Chains, Certificates for Cables, Marking Cables, Prices of Chain Cables and Chains, Historical Notes, Acts of Parliament, Statutory Tests, Charges for Testing, List of Manufacturers of Cables, &c. &c. By THOMAS W. TRAILL, F.E.R.N., M. Inst. C.E., Engineer Surveyor in Chief, Board of Trade, the Inspector of Chain Cable and Anchor Proving Establishments, and General Superintendent, Lloyd's Committee on Proving Establishments. With numerous Tables, Illustrations and Lithographic Drawings. Folio, £2 2s. cloth, bevelled boards.

"The author writes not only with a full acquaintance with scientific formulæ and details, but also with a profound and fully-instructed sense of the importance to the safety of our ships and sailors of fidelity in the manufacture of cables."—*Athenæum.*

"The business of chain cable making is well explained and illustrated. We can safely recommend this work to all in any way connected with the manufacture of chain cables and chains, as a good book."—*Nature.*

"It contains a vast amount of valuable information. Nothing seems to be wanting to make it a complete and standard work of reference on the subject."—*Nautical Magazine.*

Pocket-Book for Naval Architects and Shipbuilders.

THE NAVAL ARCHITECT'S AND SHIPBUILDER'S POCKET-BOOK of Formulæ, Rules, and Tables, and MARINE ENGINEER'S AND SURVEYOR'S Handy Book of Reference. By CLEMENT MACKROW, Member of the Institution of Naval Architects, Naval Draughtsman. Third Edition, Revised. With numerous Diagrams, &c. Fcap., 12s. 6d. strongly bound in leather.

"Should be used by all who are engaged in the construction or design of vessels. . . . Will be found to contain the most useful tables and formulæ required by shipbuilders, carefully collected from the best authorities, and put together in a popular and simple form."—*Engineer.*

"The professional shipbuilder has now, in a convenient and accessible form, reliable data for solving many of the numerous problems that present themselves in the course of his work."—*Iron.*

"There is scarcely a subject on which a naval architect or shipbuilder can require to refresh his memory which will not be found within the covers of Mr. Mackrow's book."—*English Mechanic.*

Pocket-Book for Marine Engineers.

A POCKET-BOOK OF USEFUL TABLES AND FORMULÆ FOR MARINE ENGINEERS. By FRANK PROCTOR, A.I.N.A. Third Edition. Royal 32mo, leather, gilt edges, with strap, 4s.

"We recommend it to our readers as going far to supply a long-felt want."—*Naval Science.*

"A most useful companion to all marine engineers."—*United Service Gazette.*

Lighthouses.

EUROPEAN LIGHTHOUSE SYSTEMS. Being a Report of a Tour of Inspection made in 1873. By Major GEORGE H. ELLIOT, Corps of Engineers, U.S.A. Illustrated by 51 Engravings and 31 Woodcuts. 8vo, 21s. cloth.

*** *The following are published in* WEALE'S RUDIMENTARY SERIES.

MASTING, MAST-MAKING, AND RIGGING OF SHIPS. By ROBERT KIPPING, N.A. Fifteenth Edition. 12mo, 2s. 6d. cloth boards.

SAILS AND SAIL-MAKING. Eleventh Edition, Enlarged, with an Appendix. By ROBERT KIPPING, N.A. Illustrated. 12mo, 3s. cloth boards.

NAVAL ARCHITECTURE. By JAMES PEAKE. Fifth Edition, with Plates and Diagrams. 12mo, 4s. cloth boards.

MARINE ENGINES AND STEAM VESSELS (A Treatise on). By ROBERT MURRAY, C.E., Principal Officer to the Board of Trade for the East Coast of Scotland District. Eighth Edition, thoroughly Revised, with considerable Additions, by the Author and by GEORGE CARLISLE, C.E., Senior Surveyor to the Board of Trade at Liverpool. 12mo, 5s. cloth boards.

PRACTICAL NAVIGATION. Consisting of THE SAILOR'S SEA-BOOK, by JAS. GREENWOOD and W. H. ROSSER; together with the requisite Mathematical and Nautical Tables for the Working of the Problems, by HENRY LAW, C.E. and Prof. J. R. YOUNG. Illustrated 12mo, 7s. half-bound.

MINING AND MINING INDUSTRIES.

Metalliferous Mining.

BRITISH MINING: A Treatise on the History, Discovery, Practical Development, and Future Prospects of Metalliferous Mines in the United Kingdom. By ROBERT HUNT, F.R.S., Keeper of Mining Records; Editor of "Ure's Dictionary of Arts, Manufactures, and Mines," &c. Upwards of 950 pp., with 230 Illustrations. Second Edition, Revised. Super-royal 8vo, £2 2s. cloth. [*Just published.*

*** OPINIONS OF THE PRESS.

"One of the most valuable works of reference of modern times. Mr. Hunt, as keeper of mining records of the United Kingdom, has had opportunities for such a task not enjoyed by anyone else, and has evidently made the most of them. . . . The language and style adopted are good, and the treatment of the various subjects laborious, conscientious, and scientific."—*Engineering.*

"Probably no one in this country was better qualified than Mr. Hunt for undertaking such a work. Brought into frequent and close association during a long life-time with the principal guardians of our mineral and metallurgical industries, he enjoyed a position exceptionally favourable for collecting the necessary information. The use which he has made of his opportunities is sufficiently attested by the dense mass of information crowded into the handsome volume which has just been published. . . . In placing before the reader a sketch of the present position of British Mining, Mr. Hunt treats his subject so fully and illustrates it so amply that this section really forms a little treatise on practical mining. . . . The book is, in fact, a treasure-house of statistical information on mining subjects, and we know of no other work embodying so great a mass of matter of this kind. Were this the only merit of Mr. Hunt's volume it would be sufficient to render it indispensable in the library of everyone interested in the development of the mining and metallurgical industries of this country."—*Athenæum.*

"A mass of information not elsewhere available, and of the greatest value to those who may be interested in our great mineral industries."—*Engineer.*

"A sound, business-like collection of interesting facts. . . . The amount of information Mr. Hunt has brought together is enormous. . . . The volume appears likely to convey more instruction upon the subject than any work hitherto published."—*Mining Journal.*

"The work will be for the mining industry what Dr. Percy's celebrated treatise has been for the metallurgical—a book that cannot with advantage be omitted from the library."—*Iron and Coal Trades Review.*

"The literature of mining has hitherto possessed no work approaching in importance to that which has just been published. There is much in Mr. Hunt's valuable work that every shareholder in a mine should read with close attention. The entire subject of practical mining—from the first search for the lode to the latest stages of dressing the ore—is dealt with in a masterly manner."—*Academy.*

Coal and Iron.

THE COAL AND IRON INDUSTRIES OF THE UNITED KINGDOM. Comprising a Description of the Coal Fields, and of the Principal Seams of Coal, with Returns of their Produce and its Distribution, and Analyses of Special Varieties. Also an Account of the occurrence of Iron Ores in Veins or Seams; Analyses of each Variety; and a History of the Rise and Progress of Pig Iron Manufacture since the year 1740, exhibiting the Economies introduced in the Blast Furnaces for its Production and Improvement. By RICHARD MEADE, Assistant Keeper of Mining Records. With Maps of the Coal Fields and Ironstone Deposits of the United Kingdom. 8vo, £1 8s. cloth.

"The book is one which must find a place on the shelves of all interested in coal and iron production, and in the iron, steel, and other metallurgical industries."—*Engineer.*

"Of this book we may unreservedly say that it is the best of its class which we have ever met. . . . A book of reference which no one engaged in the iron or coal trades should omit from his library."—*Iron and Coal Trades Review.*

"An exhaustive treatise and a valuable work of reference."—*Mining Journal.*

Prospecting for Gold and other Metals.

THE PROSPECTOR'S HANDBOOK: A Guide for the Prospector and Traveller in Search of Metal-Bearing or other Valuable Minerals. By J. W. ANDERSON, M.A. (Camb.), F.R.G.S., Author of "Fiji and New Caledonia." Third Edition, Revised, with Additions. Small crown 8vo, 3s. 6d. cloth. [*Just published.*

"Will supply a much felt want, especially among Colonists, in whose way are so often thrown many mineralogical specimens the value of which it is difficult for anyone, not a specialist, to determine. The author has placed his instructions before his readers in the plainest possible terms, and his book is the best of its kind."—*Engineer.*

"How to find commercial minerals, and how to identify them when they are found, are the leading points to which attention is directed. The author has managed to pack as much practical detail into his pages as would supply material for a book three times its size."—*Mining Journal.*

"Those toilers who explore the trodden or untrodden tracks on the face of the globe will find much that is useful to them in this book."—*Athenæum.*

Mining Notes and Formulæ.

NOTES AND FORMULÆ FOR MINING STUDENTS. By JOHN HERMAN MERIVALE, M.A., Certificated Colliery Manager, Professor of Mining in the Durham College of Science, Newcastle-upon-Tyne. Second Edition, carefully Revised. Small crown 8vo, cloth, price 2s. 6d.
[*Just published.*

☞ *This book consists of a collection of notes and formulæ drawn from various sources, the authority being quoted in most instances. It is hoped that the work will be useful not only to students but to the profession.*

The principal sources of information upon mining matters are the Transactions of the various Engineering Societies to which the student, in most of our large towns, has access. A great many references to the most familiar of them are given, so that the student who wishes to follow up a subject may be in a position to acquaint himself with details which could not be included in a work like this.

The examples of the use of the formulæ, at the end of the book, are merely given to assist students working without a teacher.

"Invaluable to anyone who is working up for an examination on mining subjects."—*Coal and Iron Trades Review.*

"The author has done his work in an exceedingly creditable manner, and has produced a book that will be of service to students, and those who are practically engaged in mining operations."—*Engineer.*

"A vast amount of technical matter of the utmost value to mining engineers, and of considerable interest to students."—*Schoolmaster.*

Mineral Surveying and Valuing.

THE MINERAL SURVEYOR AND VALUER'S COMPLETE GUIDE, comprising a Treatise on Improved Mining Surveying and the Valuation of Mining Properties, with New Traverse Tables. By WM. LINTERN, Mining and Civil Engineer. Second Edition, with an Appendix on "Magnetic and Angular Surveying," with Records of the Peculiarities of Needle Disturbances. With Four Plates of Diagrams, Plans, &c. 12mo, 4s. cloth.
[*Just published.*

"An enormous fund of information of great value."—*Mining Journal.*

"Mr. Lintern's book forms a valuable and thoroughly trustworthy guide."—*Iron and Coal Trades Review.*

"This new edition must be of the highest value to colliery surveyors, proprietors and managers."—*Colliery Guardian.*

Metalliferous Minerals and Mining.

TREATISE ON METALLIFEROUS MINERALS AND MINING. By D. C. DAVIES, F.G.S., Mining Engineer, &c., Author of "A Treatise on Slate and Slate Quarrying." Illustrated with numerous Wood Engravings. Fourth Edition. Crown 8vo, 12s. 6d. cloth.

"Neither the practical miner nor the general reader interested in mines, can have a better book for his companion and his guide."—*Mining Journal.*

"The volume is one which no student of mineralogy should be without."—*Colliery Guardian.*

"We are doing our readers a service in calling their attention to this valuable work."—*Mining World.*

"A book that will not only be useful to the geologist, the practical miner, and the metallurgist, but also very interesting to the general public."—*Iron.*

"As a history of the present state of mining throughout the world this book has a real value, and it supplies an actual want, for no such information has hitherto been brought together within such limited space."—*Athenæum.*

Earthy Minerals and Mining.

A TREATISE ON EARTHY AND OTHER MINERALS AND MINING. By D. C. DAVIES, F.G.S. Uniform with, and forming a Companion Volume to, the same Author's "Metalliferous Minerals and Mining." With 76 Wood Engravings. Second Edition. Crown 8vo, 12s. 6d. cloth.

"It is essentially a practical work, intended primarily for the use of practical men. . . . We do not remember to have met with any English work on mining matters that contains the same amount of information packed in equally convenient form."—*Academy.*

"The book is clearly the result of many years' careful work and thought, and we should be inclined to rank it as among the very best of the handy technical and trades manuals which have recently appeared."—*British Quarterly Review.*

"The volume contains a great mass of practical information, carefully methodised and presented in a very intelligible shape."—*Scotsman.*

"The subject matter of the volume will be found of high value by all—and they are a numerous class—who trade in earthy minerals."—*Athenæum.*

Underground Pumping Machinery.

MINE DRAINAGE. Being a Complete and Practical Treatise on Direct-Acting Underground Steam Pumping Machinery, with a Description of a large number of the best known Engines, their General Utility and the Special Sphere of their Action, the Mode of their Application, and their merits compared with other forms of Pumping Machinery. By STEPHEN MICHELL. 8vo, 15*s*. cloth.

"Will be highly esteemed by colliery owners and lessees, mining engineers, and students generally who require to be acquainted with the best means of securing the drainage of mines. It is a most valuable work, and stands almost alone in the literature of steam pumping machinery."—*Colliery Guardian.*

"Much valuable information is given, so that the book is thoroughly worthy of an extensive circulation amongst practical men and purchasers of machinery."—*Mining Journal.*

Mining Tools.

A MANUAL OF MINING TOOLS. For the Use of Mine Managers, Agents, Students, &c. By WILLIAM MORGANS, Lecturer on Practical Mining at the Bristol School of Mines. 12mo, 3*s*. cloth boards.

ATLAS OF ENGRAVINGS to Illustrate the above, containing 235 Illustrations of Mining Tools, drawn to scale. 4to, 4*s*. 6*d*. cloth.

"Students in the science of mining, and overmen, captains, managers, and viewers may gain practical knowledge and useful hints by the study of Mr. Morgans' manual."—*Colliery Guardian.*

"A valuable work, which will tend materially to improve our mining literature."—*Mining Journal.*

Coal Mining.

COAL AND COAL MINING: A Rudimentary Treatise on. By Sir WARINGTON W. SMYTH, M.A., F.R.S., &c., Chief Inspector of the Mines of the Crown. New Edition, Revised and Corrected. With numerous Illustrations. 12mo, 4*s*. cloth boards.

"As an outline is given of every known coal-field in this and other countries, as well as of the principal methods of working, the book will doubtless interest a very large number of readers."—*Mining Journal.*

Subterraneous Surveying.

SUBTERRANEOUS SURVEYING, Elementary and Practical Treatise on; with and without the Magnetic Needle. By THOMAS FENWICK, Surveyor of Mines, and THOMAS BAKER, C.E. Illustrated. 12mo, 3*s*. cloth boards.

NATURAL AND APPLIED SCIENCE.

Text Book of Electricity.

THE STUDENT'S TEXT-BOOK OF ELECTRICITY. By HENRY M. NOAD, Ph.D., F.R.S., F.C.S. New Edition, carefully Revised. With an Introduction and Additional Chapters, by W. H. PREECE, M.I.C.E., Vice-President of the Society of Telegraph Engineers, &c. With 470 Illustrations. Crown 8vo, 12*s*. 6*d*. cloth.

"The original plan of this book has been carefully adhered to so as to make it a reflex of the existing state of electrical science, adapted for students. . . . Discovery seems to have progressed with marvellous strides; nevertheless it has now apparently ceased, and practical applications have commenced their career; and it is to give a faithful account of these that this fresh edition of Dr. Noad's valuable text-book is launched forth."—*Extract from Introduction by W. H. Preece, Esq.*

"We can recommend Dr. Noad's book for clear style, great range of subject, a good index, and a plethora of woodcuts. Such collections as the present are indispensable."—*Athenæum.*

"Dr. Noad's text-book has earned for itself the reputation of a truly scientific manual for the student of electricity, and we gladly hail this new amended edition, which brings it once more to the front. Mr. Preece as reviser, with the assistance of Mr. H. R. Kempe and Mr. J. P. Edwards, has added all the practical results of recent invention and research to the admirable theoretical expositions of the author, so that the book is about as complete and advanced as it is possible for any book to be within the limits of a text-book."—*Telegraphic Journal.*

Electricity.

A MANUAL OF ELECTRICITY: Including Galvanism, Magnetism, Dia-Magnetism, Electro-Dynamics, Magno-Electricity, and the Electric Telegraph. By HENRY M. NOAD, Ph.D., F.R.S., F.C.S. Fourth Edition. With 500 Woodcuts. 8vo, £1 4*s*. cloth.

"The accounts given of electricity and galvanism are not only complete in a scientific sense but, which is a rarer thing, are popular and interesting."—*Lancet.*

"It is worthy of a place in the library of every public institution."—*Mining Journal.*

Electric Light.

ELECTRIC LIGHT: Its Production and Use. Embodying Plain Directions for the Treatment of Voltaic Batteries, Electric Lamps, and Dynamo-Electric Machines. By J. W. URQUHART, C.E., Author of "Electro-plating." Second Edition, with large Additions and 128 Illusts. 7s. 6d. cloth.

"The book is by far the best that we have yet met with on the subject."—*Athenæum.*

"It is the only work at present available which gives, in language intelligible for the most part o the ordinary reader, a general but concise history of the means which have been adopted up to he present time in producing the electric light."—*Metropolitan.*

"The book contains a general account of the means adopted in producing the electric light, ot only as obtained from voltaic or galvanic batteries, but treats at length of the dynamo-electric iachine in several of its forms."—*Colliery Guardian.*

Electric Lighting.

THE ELEMENTARY PRINCIPLES OF ELECTRIC LIGHTING. By ALAN A. CAMPBELL SWINTON, Associate S.T.E. Crown 8vo, 1s. 6d. cloth.

"Anyone who desires a short and thoroughly clear exposition of the elementary principles of lectric-lighting cannot do better than read this little work "—*Bradford Observer.*

Dr. Lardner's School Handbooks.

NATURAL PHILOSOPHY FOR SCHOOLS. By Dr. LARDNER. 328 Illustrations. Sixth Edition. One Vol, 3s. 6d. cloth.

"A very convenient class-book for junior students in private schools. It is intended to convey, 1 clear and precise terms, general notions of all the principal divisions of Physical Science."—*ritish Quarterly Review.*

ANIMAL PHYSIOLOGY FOR SCHOOLS. By Dr. LARDNER. With 190 Illustrations. Second Edition. One Vol, 3s. 6d. cloth.

"Clearly written, well arranged, and excellently illustrated."—*Gardener's Chronicle.*

Dr. Lardner's Electric Telegraph.

THE ELECTRIC TELEGRAPH. By Dr. LARDNER. Revised and Re-written by E. B. BRIGHT, F.R.A.S. 140 Illustrations. Small 8vo, 2s. 6d. cloth.

"One of the most readable books extant on the Electric Telegraph "—*English Mechanic.*

Storms.

STORMS: Their Nature, Classification, and Laws; with the Means of Predicting them by their Embodiments, the Clouds. By WM. BLASIUS. With Coloured Plates and Woodcuts. Crown 8vo, 10s. 6d. cloth.

"A very readable book . . . The fresh facts contained in its pages, collected with evident are, form a useful repository for meteorologists in the study of atmospherical disturbances . he book will pay perusal as being the production of one who gives evidence of acute observaon "—*Nature.*

The Blowpipe.

THE BLOWPIPE IN CHEMISTRY, MINERALOGY, AND GEOLOGY. Containing all known Methods of Anhydrous Analysis, many Working Examples, and Instructions for Making Apparatus. By Lieut.-Colonel W. A. ROSS, R.A. With 120 Illustrations. Cr. 8vo, 3s. 6d. cloth.

"The student who goes conscientiously through the course of experimentation here laid down ill gain a better insight into inorganic chemistry and mineralogy than if he had 'got up' any of ie best text-books of the day, and passed any number of examinations in their contents."—*Chemial News.*

The Military Sciences.

AIDE-MEMOIRE TO THE MILITARY SCIENCES. Framed from Contributions of Officers and others connected with the different Services. Originally edited by a Committee of the Corps of Royal Engineers. Second Edition, most carefully revised by an Officer of the Corps, with many Additions; containing nearly 350 Engravings and many hundred Woodcuts. Three Vols., royal 8vo, extra cloth boards, and lettered, £4 10s.

"A compendious encyclopædia of military knowledge, to which we are greatly indebted."—*dinburgh Review.*

Field Fortification.

A TREATISE ON FIELD FORTIFICATION, THE ATTACK OF FORTRESSES, MILITARY MINING, AND RECONNOITRING. By Colonel I. S. MACAULAY, late Professor of Fortification in the R.M.A., Woolwich. Sixth Edition, crown 8vo, cloth, with separate Atlas of 12 Plates, 12s.

Temperaments.

OUR TEMPERAMENTS, THEIR STUDY AND THEIR TEACHING. A Popular Outline. By ALEXANDER STEWART, F.R.C.S. Edin. In one large 8vo volume, with 30 Illustrations, including A Selection from Lodge's "Historical Portraits," showing the Chief Forms of Faces. Price 15*s*. cloth, gilt top.

"The book is exceedingly interesting, even for those who are not systematic students of anthropology. . . . To those who think the proper study of mankind is man, it will be full of attraction."—*Daily Telegraph.*

"The author's object is to enable a student to read a man's temperament in his aspect. The work is well adapted to its end. It is worthy of the attention of students of human nature."—*Scotsman.*

"The volume is heavy to hold, but light to read. Though the author has treated his subject exhaustively, he writes in a popular and pleasant manner that renders it attractive to the general reader."—*Punch.*

Pneumatics and Acoustics.

PNEUMATICS: including Acoustics and the Phenomena of Wind Currents, for the Use of Beginners. By CHARLES TOMLINSON, F.R.S., F.C.S., &c. Fourth Edition, Enlarged. With numerous Illustrations. 12mo, 1*s*. 6*d*. cloth. [*Just published.*

"Beginners in the study of this important application of science could not have a better manual."—*Scotsman.*

"A valuable and suitable text-book for students of Acoustics and the Phenomena of Wind Currents."—*Schoolmaster.*

Conchology.

A MANUAL OF THE MOLLUSCA: Being a Treatise on Recent and Fossil Shells. By S. P. WOODWARD, A.L.S., F.G.S., late Assistant Palæontologist in the British Museum. Fifth Edition. With an Appendix on *Recent and Fossil Conchological Discoveries*, by RALPH TATE, A.L.S., F.G.S. Illustrated by A. N. WATERHOUSE and JOSEPH WILSON LOWRY. With 23 Plates and upwards of 300 Woodcuts. Crown 8vo, 7*s*. 6*d*. cloth boards.

"A most valuable storehouse of conchological and geological information."—*Science Gossip.*

Astronomy.

ASTRONOMY. By the late Rev. ROBERT MAIN, M.A., F.R.S., formerly Radcliffe Observer at Oxford. Third Edition, Revised and Corrected to the present time, by WILLIAM THYNNE LYNN, B.A., F.R.A.S., formerly of the Royal Observatory, Greenwich. 12mo, 2*s*. cloth limp.

"A sound and simple treatise, very carefully edited, and a capital book for beginners."—*Knowledge.*

"Accurately brought down to the requirements of the present time by Mr. Lynn."—*Educational Times.*

Geology.

RUDIMENTARY TREATISE ON GEOLOGY, PHYSICAL AND HISTORICAL. Consisting of "Physical Geology," which sets forth the leading Principles of the Science; and "Historical Geology," which treats of the Mineral and Organic Conditions of the Earth at each successive epoch, especial reference being made to the British Series of Rocks. By RALPH TATE, A.L.S., F.G.S., &c., &c. With 250 Illustrations. 12mo, 5*s*. cloth boards.

"The fulness of the matter has elevated the book into a manual. Its information is exhaustive and well arranged."—*School Board Chronicle.*

Geology and Genesis.

THE TWIN RECORDS OF CREATION; or, Geology and Genesis: their Perfect Harmony and Wonderful Concord. By GEORGE W. VICTOR LE VAUX. Numerous Illustrations. Fcap. 8vo, 5*s*. cloth.

"A valuable contribution to the evidences of Revelation, and disposes very conclusively of the arguments of those who would set God's Works against God's Word. No real difficulty is shirked, and no sophistry is left unexposed."—*The Rock.*

"The remarkable peculiarity of this author is that he combines an unbounded admiration of science with an unbounded admiration of the Written record. The two impulses are balanced to a nicety; and the consequence is that difficulties, which to minds less evenly poised would be serious, find immediate solutions of the happiest kinds."—*London Review.*

DR. LARDNER'S HANDBOOKS OF NATURAL PHILOSOPHY.

THE HANDBOOK OF MECHANICS. Enlarged and almost re-written by BENJAMIN LOEWY, F.R.A.S. With 378 Illustrations. Post 8vo, 6s. cloth.

"The perspicuity of the original has been retained, and chapters which had become obsolete have been replaced by others of more modern character. The explanations throughout are studiously popular, and care has been taken to show the application of the various branches of physics to the industrial arts, and to the practical business of life."—*Mining Journal.*

"Mr. Loewy has carefully revised the book, and brought it up to modern requirements."—*Nature.*

"Natural philosophy has had few exponents more able or better skilled in the art of popularising the subject than Dr. Lardner; and Mr. Loewy is doing good service in fitting this treatise, and the others of the series, for use at the present time."—*Scotsman.*

THE HANDBOOK OF HYDROSTATICS AND PNEUMATICS. New Edition, Revised and Enlarged, by BENJAMIN LOEWY, F.R.A.S. With 236 Illustrations. Post 8vo, 5s. cloth.

"For those 'who desire to attain an accurate knowledge of physical science without the profound methods of mathematical investigation,' this work is not merely intended, but well adapted."—*Chemical News.*

"The volume before us has been carefully edited, augmented to nearly twice the bulk of the former edition, and all the most recent matter has been added. . . . It is a valuable text-book."—*Nature.*

"Candidates for pass examinations will find it, we think, specially suited to their requirements." *English Mechanic.*

THE HANDBOOK OF HEAT. Edited and almost entirely re-written by BENJAMIN LOEWY, F.R.A.S., &c. 117 Illustrations. Post 8vo, 6s. cloth.

"The style is always clear and precise, and conveys instruction without leaving any cloudiness or lurking doubts behind."—*Engineering.*

"A most exhaustive book on the subject on which it treats, and is so arranged that it can be understood by all who desire to attain an accurate knowledge of physical science . . . . Mr. Loewy has included all the latest discoveries in the varied laws and effects of heat."—*Standard.*

"A complete and handy text-book for the use of students and general readers."—*English Mechanic.*

THE HANDBOOK OF OPTICS. By DIONYSIUS LARDNER, D.C.L., formerly Professor of Natural Philosophy and Astronomy in University College, London. New Edition. Edited by T. OLVER HARDING, B.A. Lond., of University College, London. With 298 Illustrations. Small 8vo, 448 pages, 5s. cloth.

"Written by one of the ablest English scientific writers, beautifully and elaborately illustrated." *Mechanic's Magazine.*

THE HANDBOOK OF ELECTRICITY, MAGNETISM, AND ACOUSTICS. By Dr. LARDNER. Ninth Thousand. Edit. by GEORGE CAREY FOSTER, B.A., F.C.S. With 400 Illustrations. Small 8vo, 5s. cloth.

"The book could not have been entrusted to anyone better calculated to preserve the terse and 'd style of Lardner, while correcting his errors and bringing up his work to the present state of 'ntific knowledge."—*Popular Science Review.*

*** *The above Five Volumes, though each is Complete in itself, form* A COMPLETE COURSE OF NATURAL PHILOSOPHY.

Dr. Lardner's Handbook of Astronomy.

THE HANDBOOK OF ASTRONOMY. Forming a Companion to the "Handbook of Natural Philosophy." By DIONYSIUS LARDNER, D.C.L., formerly Professor of Natural Philosophy and Astronomy in University College, London. Fourth Edition. Revised and Edited by EDWIN DUNKIN, F.R.A.S., Royal Observatory, Greenwich. With 38 Plates and upwards of 100 Woodcuts. In One Vol., small 8vo, 550 pages, 9s. 6d. cloth.

"Probably no other book contains the same amount of information in so compendious and well-arranged a form—certainly none at the price at which this is offered to the public."—*Athenæum.*

"We can do no other than pronounce this work a most valuable manual of astronomy, and we strongly recommend it to all who wish to acquire a general—but at the same time correct—acquaintance with this sublime science."—*Quarterly Journal of Science.*

"One of the most deservedly popular books on the subject . . . We would recommend not only the student of the elementary principles of the science, but he who aims at mastering the higher and mathematical branches of astronomy, not to be without this work beside him."—*Practical Magazine.*

DR. LARDNER'S MUSEUM OF SCIENCE AND ART.

THE MUSEUM OF SCIENCE AND ART. Edited by DIONYSIUS LARDNER, D.C.L., formerly Professor of Natural Philosophy and Astronomy in University College, London. With upwards of 1,200 Engravings on Wood. In 6 Double Volumes, £1 1s., in a new and elegant cloth binding; or handsomely bound in half-morocco, 31s. 6*d*.

Contents:

The Planets: Are they Inhabited Worlds?—Weather Prognostics—Popular Fallacies in Questions of Physical Science—Latitudes and Longitudes—Lunar Influences—Meteoric Stones and Shooting Stars—Railway Accidents—Light—Common Things: Air—Locomotion in the United States—Cometary Influences—Common Things: Water—The Potter's Art—Common Things: Fire—Locomotion and Transport, their Influence and Progress—The Moon—Common Things: The Earth—The Electric Telegraph—Terrestrial Heat—The Sun—Earthquakes and Volcanoes—Barometer, Safety Lamp, and Whitworth's Micrometric Apparatus—Steam—The Steam Engine—The Eye—The Atmosphere—Time—Common Things: Pumps—Common Things: Spectacles, the Kaleidoscope—Clocks and Watches—Microscopic Drawing and Engraving—Locomotive—Thermometer—New Planets: Leverrier and Adams's Planet—Magnitude and Minuteness—Common Things: The Almanack—Optical Images—How to observe the Heavens—Common Things: The Looking-glass—Stellar Universe—The Tides—Colour—Common Things: Man—Magnifying Glasses—Instinct and Intelligence—The Solar Microscope—The Camera Lucida—The Magic Lantern—The Camera Obscura—The Microscope—The White Ants: Their Manners and Habits—The Surface of the Earth, or First Notions of Geography—Science and Poetry—The Bee—Steam Navigation—Electro-Motive Power—Thunder, Lightning, and the Aurora Borealis—The Printing Press—The Crust of the Earth—Comets—The Stereoscope—The Pre-Adamite Earth—Eclipses—Sound.

*** OPINIONS OF THE PRESS.

"This series, besides affording popular but sound instruction on scientific subjects, with which the humblest man in the country ought to be acquainted, also undertakes that teaching of 'Common Things' which every well-wisher of his kind is anxious to promote. Many thousand copies of this serviceable publication have been printed, in the belief and hope that the desire for instruction and improvement widely prevails; and we have no fear that such enlightened faith will meet with [illegible]

"A cheap and interesting publication, alike informing and attractive. The papers combine subjects of importance and great scientific knowledge, considerable inductive powers, and a popular style of treatment."—*Spectator*.

"The 'Museum of Science and Art' is the most valuable contribution that has ever been made to the Scientific Instruction of every class of society."—Sir DAVID BREWSTER, in the *North British Review*.

"Whether we consider the liberality and beauty of the illustrations, the charm of the writing, or the durable interest of the matter, we must express our belief that there is hardly to be found among the new books one that would be welcomed by people of so many ages and classes as a valuable present."—*Examiner*.

*** *Separate books formed from the above, suitable for Workmen's Libraries, Science Classes, etc.*

Common Things Explained. Containing Air, Earth, Fire, Water, Time, Man, the Eye, Locomotion, Colour, Clocks and Watches, &c. 233 Illustrations, cloth gilt, 5s.

The Microscope. Containing Optical Images, Magnifying Glasses, Origin and Description of the Microscope, Microscopic Objects, the Solar Microscope, Microscopic Drawing and Engraving, &c. 147 Illustrations, cloth gilt, 2s.

Popular Geology. Containing Earthquakes and Volcanoes, the Crust of the Earth, &c. 201 Illustrations, cloth gilt, 2s. 6*d*.

Popular Physics. Containing Magnitude and Minuteness, the Atmosphere, Meteoric Stones, Popular Fallacies, Weather Prognostics, the Thermometer, the Barometer, Sound, &c. 85 Illustrations, cloth gilt, 2s. 6*d*.

Steam and its Uses. Including the Steam Engine, the Locomotive, and Steam Navigation. 89 Illustrations, cloth gilt, 2s.

Popular Astronomy. Containing How to observe the Heavens—The Earth, Sun, Moon, Planets, Light, Comets, Eclipses, Astronomical Influences, &c. 182 Illustrations, 4s. 6*d*.

The Bee and White Ants: Their Manners and Habits. With Illustrations of Animal Instinct and Intelligence. 135 Illustrations, cloth gilt, 2s.

The Electric Telegraph Popularized. To render intelligible to all who can Read, irrespective of any previous Scientific Acquirements, the various forms of Telegraphy in Actual Operation. 100 Illustrations, cloth gilt, 1s. 6*d*.

COUNTING-HOUSE WORK, TABLES, etc.

Accounts for Manufacturers.

FACTORY ACCOUNTS: Their Principles and Practice. A Handbook for Accountants and Manufacturers, with Appendices on the Nomenclature of Machine Details; the Income Tax Acts, the Rating of Factories; Fire and Boiler Insurance; the Factory and Workshop Acts, &c., including also a Glossary of Terms and a large number of Specimen Rulings. By EMILE GARCKE and J. M. FELLS. Second Edition. Demy 8vo, 250 pages, price 10s 6d. strongly bound. [*Just published.*

"One of the most important works ever published dealing with these matters. The authors have treated the subject from the standpoint of the factory, as practical men speaking to practical men, and not, as has been too often the case, as schoolmasters to schoolboys."—*Electrician.*

"A very interesting description of the requirements of Factory Accounts. . . . the principle of assimilating the Factory Accounts to the general commercial books is one which we thoroughly agree with."—*Accountants' Journal.*

"Characterised by extreme thoroughness. There are few owners of Factories who would not derive great benefit from the perusal of this most admirable work."—*Local Government Chronicle.*

Foreign Commercial Correspondence.

THE FOREIGN COMMERCIAL CORRESPONDENT: Being Aids to Commercial Correspondence in Five Languages—English, French, German, Italian and Spanish. By CHARLES E. BAKER. Crown 8vo, price about 5s. [*In preparation.*

Intuitive Calculations.

THE COMPENDIOUS CALCULATOR; or, Easy and Concise Methods of Performing the various Arithmetical Operations required in Commercial and Business Transactions, together with Useful Tables. By DANIEL O'GORMAN. Corrected and Extended by J. R. YOUNG, formerly Professor of Mathematics at Belfast College. Twenty-sixth Edition, carefully Revised by C. NORRIS. Fcap. 8vo, 3s. 6d. strongly half-bound in leather.

"It would be difficult to exaggerate the usefulness of a book like this to everyone engaged in commerce or manufacturing industry. It is crammed full of rules and formulæ for shortening and employing calculations."—*Knowledge.*

"Supplies special and rapid methods for all kinds of calculations. Of great utility to persons engaged in any kind of commercial transactions."—*Scotsman.*

Modern Metrical Units and Systems.

MODERN METROLOGY: A Manual of the Metrical Units and Systems of the Present Century. With an Appendix containing a proposed English System. By LOWIS D'A. JACKSON, A.M. Inst. C.E., Author of "Aid to Survey Practice," &c. Large crown 8vo, 12s. 6d. cloth.

"The author has brought together much valuable and interesting information. . . . We cannot but recommend the work to the consideration of all interested in the practical reform of our weights and measures."—*Nature.*

"For exhaustive tables of equivalent weights and measures of all sorts, and for clear demonstrations of the effects of the various systems that have been proposed or adopted, Mr. Jackson's treatise is without a rival."—*Academy.*

The Metric System and the British Standards.

A SERIES OF METRIC TABLES, in which the British Standard Measures and Weights are compared with those of the Metric System at present in Use on the Continent. By C. H. DOWLING, C.E. 8vo, 10s. 6d. strongly bound.

"Their accuracy has been certified by Professor Airy, the Astronomer-Royal."—*Builder.*

"Mr. Dowling's Tables are well put together as a ready-reckoner for the conversion of one system into the other."—*Athenæum.*

Iron and Metal Trades' Calculator.

THE IRON AND METAL TRADES' COMPANION. For expeditiously ascertaining the Value of any Goods bought or sold by Weight, from 1s. per cwt. to 112s. per cwt., and from one farthing per pound to one shilling per pound. Each Table extends from one pound to 100 tons. To which are appended Rules on Decimals, Square and Cube Root, Mensuration of Superficies and Solids, &c.; Tables of Weights of Materials, and other Useful Memoranda. By THOS. DOWNIE. 396 pp., 9s. Strongly bound in leather.

"A most useful set of tables, and will supply a want, for nothing like them before existed."—*Building News.*

"Although specially adapted to the iron and metal trades, the tables will be found useful in every other business in which merchandise is bought and sold by weight."—*Railway News.*

Calculator for Numbers and Weights Combined.

THE COMBINED NUMBER AND WEIGHT CALCULATOR. Containing upwards of 250,000 Separate Calculations, showing at a glance the value at 421 different rates, ranging from $\frac{1}{128}$th of a Penny to 20s. each, or per cwt., and £20 per ton, of any number of articles consecutively, from 1 to 470.—Any number of cwts., qrs., and lbs., from 1 cwt. to 470 cwts.—Any number of tons, cwts., qrs., and lbs., from 1 to 23½ tons. By WILLIAM CHADWICK, Public Accountant. Imp. 8vo, 30s. strongly bound for Office wear and tear.

☞ *This comprehensive and entirely unique and original Calculator is adapted for the use of Accountants and Auditors, Railway Companies, Canal Companies, Shippers, Shipping Agents, General Carriers, etc. Ironfounders, Brassfounders, Metal Merchants, Iron Manufacturers, Ironmongers, Engineers, Machinists, Boiler Makers, Millwrights, Roofing, Bridge and Girder Makers, Colliery Proprietors, etc. Timber Merchants, Builders, Contractors, Architects, Surveyors, Auctioneers, Valuers, Brokers, Mill Owners and Manufacturers, Mill Furnishers, Merchants and General Wholesale Tradesmen.*

*** OPINIONS OF THE PRESS.

"The book contains the answers to questions, and not simply a set of ingenious puzzle methods of arriving at results. It is as easy of reference for any answer or any number of answers as a dictionary, and the references are even more quickly made. For making up accounts or estimates, the book must prove invaluable to all who have any considerable quantity of calculations involving price and measure in any combination to do."—*Engineer.*

"The most complete and practical ready reckoner which it has been our fortune yet to see. It is difficult to imagine a trade or occupation in which it could not be of the greatest use, either in saving human labour or in checking work."—*The Miller.*

"The most perfect work of the kind yet prepared."—*Glasgow Herald.*

Comprehensive Weight Calculator.

THE WEIGHT CALCULATOR. Being a Series of Tables upon a New and Comprehensive Plan, exhibiting at One Reference the exact Value of any Weight from 1 lb. to 15 tons, at 300 Progressive Rates, from 1*d.* to 168*s.* per cwt., and containing 186,000 Direct Answers, which, with their Combinations, consisting of a single addition (mostly to be performed at sight), will afford an aggregate of 10,266,000 Answers; the whole being calculated and designed to ensure correctness and promote despatch. By HENRY HARBEN, Accountant. Fourth Edition, carefully Corrected. Royal 8vo, strongly half-bound, £1 5s. [*Just published.*

"A practical and useful work of reference for men of business generally, it is the best of the kind we have seen."—*Ironmonger.*

"Of priceless value to business men. Its accuracy and completeness have secured for it a reputation which renders it quite unnecessary for us to say one word in its praise. It is a necessary book in all mercantile offices."—*Sheffield Independent.*

Comprehensive Discount Guide.

THE DISCOUNT GUIDE. Comprising several Series of Tables for the use of Merchants, Manufacturers, Ironmongers, and others, by which may be ascertained the exact Profit arising from any mode of using Discounts, either in the Purchase or Sale of Goods, and the method of either Altering a Rate of Discount or Advancing a Price, so as to produce, by one operation, a sum that will realise any required profit after allowing one or more Discounts: to which are added Tables of Profit or Advance from 1¼ to 90 per cent., Tables of Discount from 1¼ to 98¾ per cent., and Tables of Commission, &c., from ⅛ to 10 per cent. By HENRY HARBEN, Accountant, Author of "The Weight Calculator." New Edition, carefully Revised and Corrected. Demy 8vo, 544 pp. half-bound, £1 5s.

"A book such as this can only be appreciated by business men, to whom the saving of time means saving of money. We have the high authority of Professor J. R. Young that the tables throughout the work are constructed upon strictly accurate principles. The work must prove of great value to merchants, manufacturers, and general traders."—*British Trade Journal.*

Iron Shipbuilders' and Merchants' Weight Tables.

IRON-PLATE WEIGHT TABLES: For Iron Shipbuilders, Engineers and Iron Merchants. Containing the Calculated Weights of upwards of 150,000 different sizes of Iron Plates, from 1 foot by 6 in. by ¼ in. to 10 feet by 5 feet by 1 in. Worked out on the basis of 40 lbs. to the square foot of Iron of 1 inch in thickness. Carefully compiled and thoroughly Revised by H. BURLINSON and W. H. SIMPSON. Oblong 4to, 25s. half-bound.

"This work will be found of great utility. The authors have had much practical experience of what is wanting in making estimates; and the use of the book will save much time in making elaborate calculations."—*English Mechanic.*

INDUSTRIAL AND USEFUL ARTS.

Soap-making.

THE ART OF SOAP-MAKING: A Practical Handbook of the Manufacture of Hard and Soft Soaps, Toilet Soaps, etc. Including many New Processes, and a Chapter on the Recovery of Glycerine from Waste Leys. By ALEXANDER WATT, Author of "Electro-Metallurgy Practically Treated," &c. With numerous Illustrations. Third Edition, Revised. Crown 8vo, 7s. 6d. cloth.

"The work will prove very useful, not merely to the technological student, but to the practical soap-boiler who wishes to understand the theory of his art."—*Chemical News.*

"Really an excellent example of a technical manual, entering, as it does, thoroughly and exhaustively both into the theory and practice of soap manufacture. The book is well and honestly done, and deserves the considerable circulation with which it will doubtless meet."—*Knowledge.*

"Mr. Watt's book is a thoroughly practical treatise on an art which has almost no literature in our language. We congratulate the author on the success of his endeavour to fill a void in English technical literature."—*Nature.*

Leather Manufacture.

THE ART OF LEATHER MANUFACTURE. Being a Practical Handbook, in which the Operations of Tanning, Currying, and Leather Dressing are fully Described, and the Principles of Tanning Explained, and many Recent Processes introduced; as also Methods for the Estimation of Tannin, and a Description of the Arts of Glue Boiling, Gut Dressing, &c. By ALEXANDER WATT, Author of "Soap-Making," "Electro-Metallurgy," &c. With numerous Illustrations. Second Edition. Crown 8vo, 9s. cloth. [*Just published.*

"A sound, comprehensive treatise on tanning and its accessories. The book is an eminently valuable production, which redounds to the credit of both author and publishers."—*Chemical Review.*

"This volume is technical without being tedious, comprehensive and complete without being prosy, and it bears on every page the impress of a master hand. We have never come across a better trade treatise, nor one that so thoroughly supplied an absolute want."—*Shoe and Leather Trades' Chronicle.*

Boot and Shoe Making.

THE ART OF BOOT AND SHOE-MAKING. A Practical Handbook, including Measurement, Last-Fitting, Cutting-Out, Closing and Making, with a Description of the most approved Machinery employed. By JOHN B. LENO, late Editor of *St. Crispin*, and *The Boot and Shoe-Maker.* With numerous Illustrations. Second Edition. Crown 8vo, 2s. 6d. cloth. [*Just published.*

"This excellent treatise is by far the best work ever written on the subject. A new work, embracing all modern improvements, was much wanted. This want is now satisfied. The chapter on clicking, which shows how waste may be prevented, will save fifty times the price of the book." —*Scottish Leather Trader.*

"This volume is replete with matter well worthy the perusal of boot and shoe manufacturers and experienced craftsmen, and instructive and valuable in the highest degree to all young beginners and craftsmen in the trade of which it treats."—*Leather Trades' Circular.*

Dentistry.

MECHANICAL DENTISTRY: A Practical Treatise on the Construction of the various kinds of Artificial Dentures. Comprising also Useful Formulæ, Tables and Receipts for Gold Plate, Clasps, Solders, &c. &c. By CHARLES HUNTER. Third Edition, Revised. With upwards of 100 Wood Engravings. Crown 8vo, 3s. 6d. cloth. [*Just published.*

"The work is very practical."—*Monthly Review of Dental Surgery.*

"We can strongly recommend Mr. Hunter's treatise to all students preparing for the profession of dentistry, as well as to every mechanical dentist."—*Dublin Journal of Medical Science.*

Wood Engraving.

A PRACTICAL MANUAL OF WOOD ENGRAVING. With a Brief Account of the History of the Art. By WILLIAM NORMAN BROWN. With numerous Illustrations. Crown 8vo, 2s. cloth.

"The author deals with the subject in a thoroughly practical and easy series of representative lessons."—*Paper and Printing Trades Journal.*

"The book is clear and complete, and will be useful to anyone wanting to understand the first elements of the beautiful art of wood engraving."—*Graphic.*

Paper Making.

A TREATISE ON PAPER; with an Outline of its Manufacture, Complete Tables of Sizes, etc. For Printers and Stationers. By RICHARDSON PARKINSON. 8vo, 3s. cloth; 2s. 6d. paper wrapper.

"An admirable handbook by a man who understands his subject."—*Printers' Register.*

LOCKWOOD'S HANDYBOOKS FOR HANDICRAFTS.

☞ *These Handybooks are written to supply Handicraftsmen with information on workshop practice, and are intended to convey, in plain language, technical knowledge of the several crafts. Workshop terms are used, and workshop practice described, the text being freely illustrated with drawings of modern tools, appliances and processes, useful alike to the young beginner and to the old hand, whose range of experience has been narrowed under a system of divided labour, as well as to amateurs.*

☞ *The following Volumes are already published.*

Metal Turning.

THE METAL TURNER'S HANDYBOOK. A Practical Manual for Workers at the Foot-Lathe: Embracing Information on the Tools, Appliances and Processes employed in Metal Turning. By PAUL N. HASLUCK, A.I.M.E., Author of "Lathe-Work." With upwards of One Hundred Illustrations. Second Edition, Revised. Cr. 8vo, 2s. cloth. [*Just published.*

"Altogether admirably adapted to initiate students into the art of turning."—*Leicester Po*

"Clearly and concisely written, excellent in every way, we heartily commend it to all interested in metal turning."—*Mechanical World.*

"With the assistance of a clever master, a clear and vivid expounder, and an abundance of illustrations, the work lets handicraftsmen know what are the resources of the turning-lathe and how these may be developed."—*Dundee Advertiser.*

Wood Turning.

THE WOOD TURNER'S HANDYBOOK. A Practical Manual for Workers at the Lathe: Embracing Information on the Tools, Appliances and Processes Employed in Wood Turning. By PAUL N. HASLUCK, A.I.M.E., Author of "Lathe-Work," "The Metal Turner's Handybook," &c. With upwards of One Hundred Illustrations. Crown 8vo, 2s. cloth. [*Just published.*

"The volume is well and clearly written in a lucid style, and all the instructions are fully given. It will be found of great value to workmen and amateurs, and forms a safe and reliable guide to every branch of the lathe manipulation."—*Carpenter and Builder.*

"An excellent manual for workers at the lathe."—*Glasgow Herald.*

"We recommend the book to young turners and amateurs. A multitude of workmen have hitherto sought in vain for a manual of this special industry."—*Mechanical World.*

Watch Repairing.

THE WATCH JOBBER'S HANDYBOOK. A Practical Manual on Cleaning, Repairing and Adjusting. Embracing Information on the Tools, Materials, Appliances and Processes Employed in Watchwork. By PAUL N. HASLUCK, A.I.M.E., Author of "Lathe-Work," "The Metal Turner's Handy-Book," "The Wood Turner's Handybook," &c. With upwards of One Hundred Illustrations. Crown 8vo, 2s. cloth. [*Just published.*

"Written in a clear style exactly suited to beginners and amateurs. We heartily recommend it."—*Practical Engineer.*

"We recommend it to craftsmen in watchmaking as a useful and well-written grammar of their art."—*Scotsman.*

"All young persons connected with the trade should acquire and study this excellent, and at the same time, inexpensive work."—*Clerkenwell Chronicle.*

Pattern Making.

THE PATTERN MAKER'S HANDYBOOK. A Practical Manual, embracing Information on the Tools, Materials and Appliances employed in Constructing Patterns for Founders. By PAUL N. HASLUCK, A.I.M.E. With One Hundred Illustrations. Cr. 8vo, 2s. cloth. [*Just published.*

"Mr. Hasluck's 'Lathe Work' and kindred productions have acquired a high reputation. His new volume, 'Pattern Making,' contains invaluable advice, and furnishes the studious workman with a very large amount of practical information."—*Lloyd's News.*

"Especially useful to the beginner. We commend it to all who are interested in the counsels it so ably gives."—*Colliery Guardian.*

"This handy volume contains sound information of considerable value to students and artificers."—*Hardware Trade Journal.*

Mechanical Manipulation.

THE MECHANIC'S WORKSHOP HANDYBOOK. A Practical Manual on Mechanical Manipulation. Embracing Information on various Handicraft Processes, with Useful Notes and Miscellaneous Memoranda. By PAUL N. HASLUCK, A.I.M.E. Author of "Lathe-Work," "The Metal Turner's Handybook," "The Wood Turner's Handybook." &c. Crown 8vo, 2s. cloth. [*Just ready.*

Electrolysis of Gold, Silver, Copper, etc.

ELECTRO-DEPOSITION: A Practical Treatise on the Electrolysis of Gold, Silver, Copper, Nickel, and other Metals and Alloys. With descriptions of Voltaic Batteries, Magnet and Dynamo-Electric Machines, Thermopiles, and of the Materials and Processes used in every Department of the Art, and several Chapters on *ELECTRO-METALLURGY.* By ALEXANDER WATT, Author of "Electro-Metallurgy," &c. With numerous Illustrations. Second Edition, Revised and Corrected. Crown 8vo, 9s. cloth. [*Just published.*

"Evidently written by a practical man who has spent a long period of time in electro-plate workshops. The information given respecting the details of workshop manipulation is remarkably complete. . . . Mr. Watt's book will prove of great value to electro-depositors, jewellers, and various other workers in metal."—*Nature.*

"Eminently a book for the practical worker in electro-deposition. It contains minute and practical descriptions of methods, processes and materials as actually pursued and used in the workshop. Mr. Watt's book recommends itself to all interested in its subjects."—*Engineer.*

Electro-Metallurgy.

ELECTRO-METALLURGY; Practically Treated. By ALEXANDER WATT, F.R.S.S.A. Eighth Edition, Revised, with Additional Matter and Illustrations, including the most recent Processes. 12mo, 3s. 6d. cloth boards.

"From this book both amateur and artisan may learn everything necessary for the successful prosecution of electroplating."—*Iron.*

Electroplating.

ELECTROPLATING: A Practical Handbook. By J. W. URQUHART, C.E. With numerous Illustrations. Crown 8vo, 5s. cloth.

"The information given appears to be based on direct personal knowledge. . . Its science is sound and the style is always clear."—*Athenæum.*

Electrotyping.

ELECTROTYPING: The Reproduction and Multiplication of Printing Surfaces and Works of Art by the Electro-deposition of Metals. By J. W. URQUHART, C.E. Crown 8vo, 5s. cloth.

"The book is thoroughly practical. The reader is, therefore, conducted through the leading laws of electricity, then through the metals used by electrotypers, the apparatus, and the depositing processes, up to the final preparation of the work."—*Art Journal.*

"We can recommend this treatise, not merely to amateurs, but to those actually engaged in the trade."—*Chemical News.*

Goldsmiths' Work.

THE GOLDSMITH'S HANDBOOK. By GEORGE E. GEE, Jeweller, &c. Third Edition, considerably Enlarged. 12mo, 3s. 6d. cloth boards.

"A good, sound, technical educator, and will be generally accepted as an authority. It exactly fulfils the purpose intended."—*Horological Journal.*

"Will speedily become a standard book which few will care to be without."—*Jeweller and Metalworker.*

Silversmiths' Work.

THE SILVERSMITH'S HANDBOOK. By GEORGE E. GEE, Jeweller, &c. Second Edition, Revised, with numerous Illustrations. 12mo, 3s. 6d. cloth boards.

"The chief merit of the work is its practical character. . . . The workers in the trade will speedily discover its merits when they sit down to study it."—*English Mechanic.*

"This work forms a valuable sequel to the author's 'Goldsmith's Handbook.'"—*Silversmiths' Trade Journal.*

**** The above two works together, strongly half-bound, price 7s.*

Textile Manufacturers' Tables.

UNIVERSAL TABLES OF TEXTILE STRUCTURE. For the use of Manufacturers in every branch of Textile Trade. By JOSEPH EDMONDSON. Oblong folio, strongly bound in cloth, price 7s. 6d.

☞ *The principle on which the tables are founded is well known, and much used in the muslin manufacture, but the intricacy of the calculations hitherto required (especially where warp and weft differ in counts and in the closeness of the threads) has prevented its general application. By these tables all the adjustments may be made* without calculation. *Mere references to the proper places bring out the required information.*

"Immense labour has been bestowed on the work by the author. The tables are adapted to every mode of numbering yarns and setts, and apply to all the branches of textile manufacture."—*Textile Recorder.*

Horology.

A TREATISE ON MODERN HOROLOGY, in Theory and Practice. Translated from the French of CLAUDIUS SAUNIER, ex-Director of the School of Horology at Macon, by JULIEN TRIPPLIN, F.R.A.S., Besancon Watch Manufacturer, and EDWARD RIGG, M.A., Assayer in the Royal Mint. With Seventy-eight Woodcuts and Twenty-two Coloured Copper Plates. Second Edition. Super-royal 8vo, £2 2s. cloth, £2 10s. half-calf.

"There is no horological work in the English language at all to be compared to this production of M. Saunier's for clearness and completeness. It is alike good as a guide for the student and as a reference for the experienced horologist and skilled workman."—*Horological Journal.*

"The latest, the most complete, and the most reliable of those literary productions to which continental watchmakers are indebted for the mechanical superiority over their English brethren—in fact, the Book of Books, is M. Saunier's 'Treatise.'"—*Watchmaker, Jeweller and Silversmith.*

"This magnificent treatise is one of the most valuable and comprehensive contributions to the literature of horological art and science ever produced, and cannot be too highly commended. It is a perfect cyclopædia of watch and clockmaking."—*The Coventry Watch and Clockmaker.*

Watchmaking.

THE WATCHMAKER'S HANDBOOK. Intended as a Workshop Companion for those engaged in Watchmaking and the Allied Mechanical Arts. Translated from the French of CLAUDIUS SAUNIER, and considerably Enlarged by JULIEN TRIPPLIN, F.R.A.S., Vice-President of the Horological Institute, and EDWARD RIGG, M.A., Assayer in the Royal Mint. With Numerous Woodcuts and Fourteen Copper Plates. Second Edition, Revised. With Appendix. Crown 8vo, 9s cloth. [*Just published.*

"Each part is truly a treatise in itself. The arrangement is good and the language is clear and concise. It is an admirable guide for the young watchmaker."—*Engineering.*

"It is impossible to speak too highly of its excellence. It fulfils every requirement in a handbook intended for the use of a workman. Should be found in every workshop."—*Watch and Clockmaker.*

"This book contains an immense number of practical details bearing on the daily occupation of a watchmaker, and it will be found of great use to an army of workers."—*Watchmaker and Metalworker* (Chicago).

CHEMICAL MANUFACTURES & COMMERCE.

The Alkali Trade, Sulphuric Acid, etc.

A MANUAL OF THE ALKALI TRADE, including the Manufacture of Sulphuric Acid, Sulphate of Soda, and Bleaching Powder. By JOHN LOMAS, Alkali Manufacturer, Newcastle-upon-Tyne and London. With 232 Illustrations and Working Drawings, and containing 390 pages of Text. Second Edition, with Additions. Super-royal 8vo, £1 10s. cloth.

"This book is written by a manufacturer for manufacturers. The working details of the most approved forms of apparatus are given, and these are accompanied by no less than 232 wood engravings, all of which may be used for the purposes of construction. Every step in the manufacture is very fully described in this manual, and each improvement explained."—*Athenæum.*

"The author is not one of those clever compilers who, on short notice, will 'read up' any conceivable subject, but a practical man in the best sense of the word. We find here not merely a sound and luminous explanation of the chemical principles of the trade, but a notice of numerous matters which have a most important bearing on the successful conduct of alkali works, but which are generally overlooked by even the most experienced technological authors."—*Chemical Review.*

Brewing.

A HANDBOOK FOR YOUNG BREWERS. By HERBERT EDWARDS WRIGHT, B.A. Crown 8vo, 3s. 6*d*. cloth.

"This little volume, containing such a large amount of good sense in so small a compass, ought to recommend itself to every brewery pupil."—*Brewers' Guardian.*

Commercial Chemical Analysis.

THE COMMERCIAL HANDBOOK OF CHEMICAL ANALYSIS; or, Practical Instructions for the determination of the Intrinsic or Commercial Value of Substances used in Manufactures, in Trades, and in the Arts. By A. NORMANDY, Editor of Rose's "Treatise on Chemical Analysis." New Edition, to a great extent Re-written by HENRY M NOAD, Ph.D., F.R.S. With numerous Illustrations. Crown 8vo, 12s. 6*d*. cloth.

"We strongly recommend this book to our readers as a guide, alike indispensable to the housewife as to the pharmaceutical practitioner."—*Medical Times.*

"Essential to the analysts appointed under the new Act. The most recent results are given, and the work is well edited and carefully written."—*Nature.*

Dye-Wares and Colours.

THE MANUAL OF COLOURS AND DYE-WARES: Their Properties, Applications, Valuation, Impurities, and Sophistications. For the use of Dyers, Printers, Drysalters, Brokers, &c. By J. W. SLATER. Second Edition, Revised and greatly Enlarged. Crown 8vo, 7s. 6d. cloth.

"A complete encyclopædia of the *materia tinctoria*. The information given respecting each article is full and precise, and the methods of determining the value of articles such as these, so liable to sophistication, are given with clearness, and are practical as well as valuable."—*Chemist and Druggist.*

"There is no other work which covers precisely the same ground. To students preparing for examinations in dyeing and printing it will prove exceedingly useful."—*Chemical News.*

Pigments.

THE ARTIST'S MANUAL OF PIGMENTS. Showing their Composition, Conditions of Permanency, Non-Permanency, and Adulterations; Effects in Combination with Each Other and with Vehicles; and the most Reliable Tests of Purity. Together with the Science and Arts Department's Examination Questions on Painting. By H. C. STANDAGE. Second Edition, Revised. Small crown 8vo, 2s. 6d. cloth. [*Just published.*

"This work is indeed *multum-in-parvo*, and we can, with good conscience, recommend it to all who come in contact with pigments, whether as makers, dealers or users."—*Chemical Review.*

"This manual cannot fail to be a very valuable aid to all painters who wish their work to endure and be of a sound character; it is complete and comprehensive."—*Spectator.*

"The author supplies a great deal of very valuable information and memoranda as to the chemical qualities and artistic effect of the principal pigments used by painters."—*Builder.*

Gauging. Tables and Rules for Revenue Officers, Brewers, etc.

A POCKET BOOK OF MENSURATION AND GAUGING: Containing Tables, Rules and Memoranda for Revenue Officers, Brewers, Spirit Merchants, &c. By J. B. MANT (Inland Revenue). Oblong 18mo, 4s. leather, with elastic band. [*Just published.*

"This handy and useful book is adapted to the requirements of the Inland Revenue Department, and will be a favourite book of reference. The range of subjects is comprehensive, and the arrangement simple and clear."—*Civilian.*

"A most useful book. It should be in the hands of every practical brewer."—*Brewers' Journal.*

AGRICULTURE, FARMING, GARDENING, etc.

Agricultural Facts and Figures.

NOTE-BOOK OF AGRICULTURAL FACTS AND FIGURES FOR FARMERS AND FARM STUDENTS. By PRIMROSE MCCONNELL, Fellow of the Highland and Agricultural Society; late Professor of Agriculture, Glasgow Veterinary College. Third Edition. Royal 32mo, full roan, gilt edges, with elastic band, 4s.

"The most complete and comprehensive Note-book for Farmers and Farm Students that we have seen. It literally teems with information, and we can cordially recommend it to all connected with agriculture."—*North British Agriculturist.*

Youatt and Burn's Complete Grazier.

THE COMPLETE GRAZIER, and FARMER'S and CATTLE-BREEDER'S ASSISTANT. A Compendium of Husbandry; especially in the departments connected with the Breeding, Rearing, Feeding, and General Management of Stock; the Management of the Dairy, &c. With Directions for the Culture and Management of Grass Land, of Grain and Root Crops, the Arrangement of Farm Offices, the use of Implements and Machines, and on Draining, Irrigation, Warping, &c.; and the Application and Relative Value of Manures. By WILLIAM YOUATT, Esq., V.S. Twelfth Edition, Enlarged by ROBERT SCOTT BURN, Author of "Outlines of Modern Farming," "Systematic Small Farming," &c. One large 8vo volume, 860 pp., with 244 Illustrations, £1 1s. half-bound.

"The standard and text-book with the farmer and grazier."—*Farmers' Magazine.*

"A treatise which will remain a standard work on the subject as long as British agriculture endures."—*Mark Lane Express* (First Notice).

"The book deals with all departments of agriculture, and contains an immense amount of valuable information. It is, in fact, an encyclopædia of agriculture put into readable form, and it is the only work equally comprehensive brought down to present date. It is excellently printed on thick paper, and strongly bound, and deserves a place in the library of every agriculturist."—*Mark Lane Express* (Second Notice).

Flour Manufacture, Milling, etc.

FLOUR MANUFACTURE: A Treatise on Milling Science and Practice. By FRIEDRICH KICK, Imperial Regierungsrath, Professor of Mechanical Technology in the Imperial German Polytechnic Institute, Prague. Translated from the Second Enlarged and Revised Edition with Supplement. By H. H. P. POWLES, Assoc. Memb. Institution of Civil Engineers. Nearly 400 pp. Illustrated with 28 Folding Plates, and 167 Woodcuts. Royal 8vo, 25s. cloth. [*Just published.*

"This valuable work is, and will remain, the standard authority on the science of milling. . . The miller who has read and digested this work will have laid the foundation, so to speak, of a successful career; he will have acquired a number of general principles which he can proceed to apply. In this handsome volume we at last have the accepted text-book of modern milling in good, sound English, which has little, if any, trace of the German idiom."—*The Miller.*

"Professor Kick treats the subject so thoroughly both on its theoretical and practical sides that his work is well suited to be a text book of technical education anywhere."—*Scotsman.*

"The appearance of this celebrated work in English is very opportune, and British millers will, we are sure, not be slow in availing themselves of its pages."—*Millers' Gazette.*

Small Farming.

SYSTEMATIC SMALL FARMING; or, The Lessons of my Farm. Being an Introduction to Modern Farm Practice for Small Farmers in the Culture of Crops; The Feeding of Cattle; The Management of the Dairy, Poultry and Pigs; The Keeping of Farm Work Records; The Ensilage System, Construction of Silos, and other Farm Buildings; The Improvement of Neglected Farms, &c. By ROBERT SCOTT BURN, Author of "Outlines of Landed Estates' Management," and "Outlines of Farm Management," and Editor of "The Complete Grazier." With numerous Illustrations, crown 8vo, 6s. cloth.

"This is the completest book of its class we have seen, and one which every amateur farmer will read with pleasure and accept as a guide."—*Field.*

"Mr. Scott Burn's pages are severely practical, and the tone of the practical man is felt throughout. The book can only prove a treasure of aid and suggestion to the small farmer of intelligence and energy."—*British Quarterly Review.*

"The volume contains a vast amount of useful information. No branch of farming is left untouched, from the labour to be done to the results achieved."—*Glasgow Herald.*

Modern Farming.

OUTLINES OF MODERN FARMING. By R. SCOTT BURN. Soils, Manures, and Crops—Farming and Farming Economy—Cattle, Sheep, and Horses—Management of the Dairy, Pigs and Poultry—Utilisation of Town-Sewage, Irrigation, &c. Sixth Edition. In One Vol., 1,250 pp., half-bound, profusely Illustrated, 12s.

"The aim of the author has been to make his work at once comprehensive and trustworthy, and in this aim he has succeeded to a degree which entitles him to much credit."—*Morning Advertiser.*

"Eminently calculated to enlighten the agricultural community on the varied subjects of which it treats, and hence it should find a place in every farmer's library."—*City Press.*

"No farmer should be without this book."—*Banbury Guardian.*

Agricultural Engineering.

FARM ENGINEERING, THE COMPLETE TEXT-BOOK OF. Comprising Draining and Embanking; Irrigation and Water Supply; Farm Roads, Fences, and Gates; Farm Buildings, their Arrangement and Construction, with Plans and Estimates; Barn Implements and Machines; Field Implements and Machines; Agricultural Surveying, Levelling, &c. By Prof. JOHN SCOTT, Editor of the *Farmers' Gazette*, late Professor of Agriculture and Rural Economy at the Royal Agricultural College, Cirencester, &c. &c. In One Vol., 1,150 pages, half-bound, with over 600 Illustrations, 12s.

"Written with great care, as well as with knowledge and ability. The author has done his work well; we have found him a very trustworthy guide wherever we have tested his statements. The volume will be of great value to agricultural students."—*Mark Lane Express.*

"For a young agriculturist we know of no handy volume so likely to be more usefully studied." —*Bell's Weekly Messenger.*

English Agriculture.

THE FIELDS OF GREAT BRITAIN: A Text-Book of Agriculture, adapted to the Syllabus of the Science and Art Department. For Elementary and Advanced Students. By HUGH CLEMENTS (Board of Trade). 18mo, 2s. 6d. cloth.

"A most comprehensive volume, giving a mass of information."—*Agricultural Economist.*

"It is a long time since we have seen a book which has pleased us more, or which contains such a vast and useful fund of knowledge."—*Educational Times.*

Farm and Estate Book-keeping.

BOOK-KEEPING FOR FARMERS & ESTATE OWNERS. A Practical Treatise, presenting, in Three Plans, a System adapted to all Classes of Farms. By JOHNSON M. WOODMAN, Chartered Accountant. Crown 8vo, 3s. 6d. cloth.

"Will be found of great assistance by those who intend to commence a system of book-keeping, the author's examples being clear and explicit, and his explanations, while full and accurate, being to a large extent free from technicalities."—*Live Stock Journal.*

Farm Account Book.

WOODMAN'S YEARLY FARM ACCOUNT BOOK. Giving a Weekly Labour Account and Diary, and showing the Income and Expenditure under each Department of Crops, Live Stock, Dairy, &c. &c. With Valuation, Profit and Loss Account, and Balance Sheet at the end of the Year, and an Appendix of Forms. Ruled and Headed for Entering a Complete Record of the Farming Operations. By JOHNSON M. WOODMAN, Chartered Accountant, Author of "Book-keeping for Farmers." Folio, 7s. 6d. half-bound.

"Contains every requisite form for keeping farm accounts readily and accurately."—*Agriculture.*

Early Fruits, Flowers and Vegetables.

THE FORCING GARDEN; or, How to Grow Early Fruits, Flowers, and Vegetables. With Plans, and Estimates for Building Glass-houses, Pits and Frames. Containing also Original Plans for Double Glazing, a New Method of Growing the Gooseberry under Glass, &c. &c., and on Ventilation, Protecting Vine Borders, &c. With Illustrations. By SAMUEL WOOD. Crown 8vo, 3s. 6d. cloth.

"Mr. Wood's book is an original and exhaustive answer to the question 'How to Grow Early Fruits, Flowers and Vegetables?'"—*Land and Water.*

Good Gardening.

A PLAIN GUIDE TO GOOD GARDENING; or, How to Grow Vegetables, Fruits, and Flowers. With Practical Notes on Soils, Manures, Seeds, Planting, Laying-out of Gardens and Grounds, &c. By S. WOOD. Third Edition, with considerable Additions, &c., and numerous Illustrations. Crown 8vo, 5s. cloth.

"A very good book, and one to be highly recommended as a practical guide."—*Athenæum.*

"May be recommended to young gardeners, cottagers, and specially to amateurs, for the plain and trustworthy information it gives on common matters."—*Gardeners' Chronicle.*

Gainful Gardening.

MULTUM-IN-PARVO GARDENING; or, How to make One Acre of Land produce £620 a-year by the Cultivation of Fruits and Vegetables; also, How to Grow Flowers in Three Glass Houses, so as to realise £176 per annum clear Profit. By SAMUEL WOOD, Author of "Good Gardening," &c. Fourth and cheaper Edition, Revised, with Additions. Crown 8vo, 1s. sewed.

"We are bound to recommend it as not only suited to the case of the amateur and gentleman's gardener, but to the market grower."—*Gardeners' Magazine.*

Gardening for Ladies.

THE LADIES' MULTUM-IN-PARVO FLOWER GARDEN, and Amateurs' Complete Guide. With Illustrations. By SAMUEL WOOD. Crown 8vo, 3s. 6d. cloth.

"Full of shrewd hints and useful instructions, based on a lifetime of experience."—*Scotsman.*

Receipts for Gardeners.

GARDEN RECEIPTS. Edited by CHARLES W. QUIN. 12mo, 1s. 6d. cloth limp.

"A useful and handy book, containing a good deal of valuable information."—*Athenæum.*

Kitchen Gardening.

THE KITCHEN AND MARKET GARDEN. By Contributors to "The Garden." Compiled by C. W. SHAW. 12mo, 3s. 6d. cloth boards.

"The most valuable compendium of kitchen and market-garden work published."—*Farmer.*

Cottage Gardening.

COTTAGE GARDENING; or, Flowers, Fruits, and Vegetables for Small Gardens. By E. HOBDAY. 12mo, 1s. 6d. cloth limp.

"Contains much useful information at a small charge."—*Glasgow Herald.*

ESTATE MANAGEMENT, AUCTIONEERING, LAW, etc.

Hudson's Land Valuer's Pocket-Book.

THE LAND VALUER'S BEST ASSISTANT: Being Tables on a very much Improved Plan, for Calculating the Value of Estates. With Tables for reducing Scotch, Irish, and Provincial Customary Acres to Statute Measure, &c. By R. HUDSON, C.E. New Edition. Royal 32mo, leather, elastic band, 4s.

"This new edition includes tables for ascertaining the value of leases for any term of years; and for showing how to lay out plots of ground of certain acres in forms, square, round, &c., with valuable rules for ascertaining the probable worth of standing timber to any amount; and is of incalculable value to the country gentleman and professional man."—*Farmers' Journal.*

Ewart's Land Improver's Pocket-Book.

THE LAND IMPROVER'S POCKET-BOOK OF FORMULÆ, TABLES and MEMORANDA required in any Computation relating to the Permanent Improvement of Landed Property. By JOHN EWART, Land Surveyor and Agricultural Engineer. Second Edition, Revised. Royal 32mo, oblong, leather, gilt edges, with elastic band, 4s.

"A compendious and handy little volume."—*Spectator.*

Complete Agricultural Surveyor's Pocket-Book.

THE LAND VALUER'S AND LAND IMPROVER'S COMPLETE POCKET-BOOK. Consisting of the above Two Works bound together. Leather, gilt edges, with strap, 7s. 6d.

"Hudson's book is the best ready-reckoner on matters relating to the valuation of land and crops, and its combination with Mr. Ewart's work greatly enhances the value and usefulness of the latter-mentioned. . . . It is most useful as a manual for reference."—*North of England Farmer.*

Auctioneer's Assistant.

THE APPRAISER, AUCTIONEER, BROKER, HOUSE AND ESTATE AGENT AND VALUER'S POCKET ASSISTANT, for the Valuation for Purchase, Sale, or Renewal of Leases, Annuities and Reversions, and of property generally; with Prices for Inventories, &c. By JOHN WHEELER, Valuer, &c. Fifth Edition, re-written and greatly extended by C. NORRIS, Surveyor, Valuer, &c. Royal 32mo, 5s. cloth.

"A neat and concise book of reference, containing an admirable and clearly-arranged list of prices for inventories, and a very practical guide to determine the value of furniture, &c."—*Standard.*

"Contains a large quantity of varied and useful information as to the valuation for purchase, sale, or renewal of leases, annuities and reversions, and of property generally, with prices for inventories, and a guide to determine the value of interior fittings and other effects."—*Builder.*

Auctioneering.

AUCTIONEERS: Their Duties and Liabilities. By ROBERT SQUIBBS, Auctioneer. Demy 8vo, 10s. 6d. cloth.

"The position and duties of auctioneers treated compendiously and clearly."—*Builder.*

"Every auctioneer ought to possess a copy of this excellent work."—*Ironmonger.*

"Of great value to the profession. . . . We readily welcome this book from the fact that it treats the subject in a manner somewhat new to the profession."—*Estates Gazette.*

Legal Guide for Pawnbrokers.

THE PAWNBROKERS', FACTORS' AND MERCHANTS' GUIDE TO THE LAW OF LOANS AND PLEDGES. With the Statutes and a Digest of Cases on Rights and Liabilities, Civil and Criminal, as to Loans and Pledges of Goods, Debentures, Mercantile and other Securities. By H. C. FOLKARD, Esq., Barrister-at-Law, Author of "The Law of Slander and Libel," &c. With Additions and Corrections to 1876. Fcap. 8vo, 3s. 6d. cloth.

"This work contains simply everything that requires to be known concerning the department of the law of which it treats. We can safely commend the book as unique and very nearly perfect." —*Iron.*

"The task undertaken by Mr. Folkard has been very satisfactorily performed. . . . Such explanations as are needful have been supplied with great clearness and with due regard to brevity." *City Press.*

How to Invest.

HINTS FOR INVESTORS: Being an Explanation of the Mode of Transacting Business on the Stock Exchange. To which are added Comments on the Fluctuations and Table of Quarterly Average prices of Consols since 1759. Also a Copy of the London Daily Stock and Share List. By WALTER M. PLAYFORD, Sworn Broker. Crown 8vo, 2s. cloth.

"An invaluable guide to investors and speculators."—*Bullionist.*

Metropolitan Rating Appeals.

REPORTS OF APPEALS HEARD BEFORE THE COURT OF GENERAL ASSESSMENT SESSIONS, from the Year 1871 to 1885. By EDWARD RYDE and ARTHUR LYON RYDE. Fourth Edition, brought down to the Present Date, with an Introduction to the Valuation (Metropolis) Act, 1869, and an Appendix by WALTER C. RYDE, of the Inner Temple, Barrister-at-Law. 8vo, 16s. cloth.

"A useful work, occupying a place mid-way between a handbook for a lawyer and a guide to the surveyor. It is compiled by a gentleman eminent in his profession as a land agent, whose speciality, it is acknowledged, lies in the direction of assessing property for rating purposes."—*Land Agents' Record.*

House Property.

HANDBOOK OF HOUSE PROPERTY. A Popular and Practical Guide to the Purchase, Mortgage, Tenancy, and Compulsory Sale of Houses and Land, including the Law of Dilapidations and Fixtures; with Examples of all kinds of Valuations, Useful Information on Buildings, and Suggestive Elucidations of Fine Art. By E. L. TARBUCK, Architect and Surveyor. Fourth Edition, 12mo, 5s. cloth. [*Just published.*

"The advice is thoroughly practical."—*Law Journal.*

"This is a well-written and thoughtful work. We commend the work to the careful study of all interested in questions affecting houses and land."—*Land Agents' Record* (First Notice).

"Carefully brought up to date, and much improved by the addition of a division on fine art. —*Land Agents' Record* (Second Notice).

Inwood's Estate Tables.

TABLES FOR THE PURCHASING OF ESTATES, Freehold, Copyhold, or Leasehold; Annuities, Advowsons, etc., and for the Renewing of Leases held under Cathedral Churches, Colleges, or other Corporate bodies, for Terms of Years certain, and for Lives; also for Valuing Reversionary Estates, Deferred Annuities, Next Presentations, &c.; together with SMART'S Five Tables of Compound Interest, and an Extension of the same to Lower and Intermediate Rates. By W. INWOOD. 22nd Edition, with considerable Additions, and new and valuable Tables of Logarithms for the more Difficult Computations of the Interest of Money, Discount, Annuities, &c., by M. FEDOR THOMAN, of the Société Crédit Mobilier of Paris. 12mo, 8s. cloth.

"Those interested in the purchase and sale of estates, and in the adjustment of compensation cases, as well as in transactions in annuities, life insurances, &c., will find the present edition of eminent service."—*Engineering.*

"'Inwood's Tables' still maintain a most enviable reputation. The new issue has been enriched by large additional contributions by M. Fedor Thoman, whose carefully arranged Tables cannot fail to be of the utmost utility."—*Mining Journal.*

Agricultural and Tenant-Right Valuation.

THE AGRICULTURAL AND TENANT-RIGHT-VALUER'S ASSISTANT. A Practical Handbook on Measuring and Estimating the Contents, Weights and Values of Agricultural Produce and Timber, the Values of Estates and Agricultural Labour, Forms of Tenant-Right-Valuations, Scales of Compensation under the Agricultural Holdings Act, 1883, &c. &c. By TOM BRIGHT, Agricultural Surveyor, Author of "The Live Stock of North Devon," &c. Crown 8vo, 3s. 6d. cloth. [*Just published.*

"Full of tables and examples in connection with the valuation of tenant-right, estates, labour, contents, and weights of timber, and farm produce of all kinds. The book is well calculated to assist the valuer in the discharge of his duty."—*Agricultural Gazette.*

"An eminently practical handbook, full of practical tables and data of undoubted interest and value to surveyors and auctioneers in preparing valuations of all kinds."—*Farmer.*

"Shows at a glance the value of land, crops, and the cost of seeding, harvesting, &c. &c. It is a really practical and useful handbook, for which we anticipate a very large sale."—*Reading Mercury.*

A Complete Epitome of the Laws of this Country.

EVERY MAN'S OWN LAWYER: A Handy-book of the Principles of Law and Equity. By A BARRISTER. Twenty-fifth Edition, Reconstructed, Thoroughly Revised, and much Enlarged. Brought down to the end of last Session, and including careful Digests of—*Coroners Act*, 1887; *Probation of First Offenders Act*, 1887; *Margarine Act*, 1887; *Agricultural Holdings (England) Act*, 1883; *Cottage Gardens (Compensation for Crops) Act*, 1887; *Bankruptcy Act*, 1883; *Allotments Act*, 1887; *Merchandise Trade Marks Act*, 1887; *Truck Amendment Act*, 1887; *Water Companies (Regulation of Powers) Act*, 1887; *Registration of Deeds of Arrangements Act*, 1887. Crown 8vo, 684 pp., price 6s. 8d. (saved at every consultation!), strongly bound in cloth. [*Just published.*

*** THE BOOK WILL BE FOUND TO COMPRISE (AMONGST OTHER MATTER)—

THE RIGHTS AND WRONGS OF INDIVIDUALS—MERCANTILE AND COMMERCIAL LAW—PARTNERSHIPS, CONTRACTS AND AGREEMENTS—GUARANTEES, PRINCIPALS AND AGENTS—CRIMINAL LAW—PARISH LAW—COUNTY COURT LAW—GAME AND FISHERY LAWS—POOR MEN'S LAWSUITS—LAWS OF BANKRUPTCY—WAGERS—CHEQUES, BILLS AND NOTES—COPYRIGHT—ELECTIONS AND REGISTRATION—INSURANCE—LIBEL AND SLANDER—MARRIAGE AND DIVORCE—MERCHANT SHIPPING—MORTGAGES—SETTLEMENTS—STOCK EXCHANGE PRACTICE—TRADE MARKS AND PATENTS—TRESPASS—NUISANCES—TRANSFER OF LAND—WILLS, &c. &c. ALSO LAW FOR LANDLORD AND TENANT—MASTER AND SERVANT—HEIRS—DEVISEES AND LEGATEES—HUSBAND AND WIFE—EXECUTORS AND TRUSTEES—GUARDIAN AND WARD—MARRIED WOMEN AND INFANTS—LENDER, BORROWER AND SURETIES—DEBTOR AND CREDITOR—PURCHASER AND VENDOR—COMPANIES—FRIENDLY SOCIETIES—CLERGYMEN—CHURCHWARDENS—MEDICAL PRACTITIONERS—BANKERS—FARMERS—CONTRACTORS—STOCK BROKERS—SPORTSMEN—GAMEKEEPERS—FARRIERS—HORSE DEALERS—AUCTIONEERS—HOUSE AGENTS—INNKEEPERS—BAKERS—MILLERS—PAWNBROKERS—SURVEYORS—RAILWAYS AND CARRIERS—CONSTABLES—SEAMEN—SOLDIERS, &c. &c.

☞ *The following subjects may be mentioned as some of those which have received special attention during the present revision*:—Marriage of British Subjects Abroad; Police Constables; Pawnbrokers; Intoxicating Liquors Licensing; Domestic Servants; Landlord and Tenant; Vendors and Purchasers; Parliamentary Elections; Municipal Elections; Local Elections; Corrupt Practices at all Elections; Public Health and Local Government and Nuisances; Highways; Churchwardens; Vestry Meetings; Rates.

It is believed that the extensions and amplifications of the present edition, while intended to meet the requirements of the ordinary Englishman, will also have the effect of rendering the book useful to the legal practitioner in the country.

One result of the reconstruction and revision, with the extensive additions thereby necessitated, has been *the enlargement of the book by nearly a hundred and fifty pages*, while the price remains as before.

*** OPINIONS OF THE PRESS.

"It is a complete code of English Law, written in plain language, which all can understand. . . . . Should be in the hands of every business man, and all who wish to abolish lawyers' bills."—*Weekly Times.*

"A useful and concise epitome of the law, compiled with considerable care."—*Law Magazine.*

"A concise, cheap and complete epitome of the English law. So plainly written that he who runs may read, and he who reads may understand."—*Figaro.*

"A dictionary of legal facts well put together. The book is a very useful one."—*Spectator.*

"A work which has long been wanted, which is thoroughly well done, and which we most cordially recommend."—*Sunday Times.*

Private Bill Legislation and Provisional Orders.

HANDBOOK FOR THE USE OF SOLICITORS AND ENGINEERS Engaged in Promoting Private Acts of Parliament and Provisional Orders, for the Authorization of Railways, Tramways, Works for the Supply of Gas and Water, and other undertakings of a like character. By L. LIVINGSTON MACASSEY, of the Middle Temple, Barrister-at-Law, and Member of the Institution of Civil Engineers; Author of "Hints on Water Supply." Demy 8vo, 950 pp., price 25s. cloth. [*Just published.*

"The volume is a desideratum on a subject which can be only acquired by practical experience, and the order of procedure in Private Bill Legislation and Provisional Orders is followed. The author's suggestions and notes will be found of great value to engineers and others professionally engaged in this class of practice."—*Building News.*

"The author's double experience as an engineer and barrister has eminently qualified him for [illegible] ...nd legal point of [illegible] promoting

J. OGDEN AND CO. LIMITED, PRINTERS, GREAT SAFFRON HILL, E.C.